PRELIMINARY ASSESSMENT
ZY - WAYCROSS ARMY AIRFIELD
GAD984307942
WAYCROSS, WARE COUNTY, GEORGIA

PREPARED BY:

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October 4, 1994

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DATE: October 4, 1994

PREPARED BY: Gerald F. Foree
U.S. Environmental Protection Agency

SITE: ZY - WAYCROSS ARMY AIRFIELD
Waycross, Ware County, Georgia
EPA ID No. GAD984307942
Lan ID No. 5845

1. INTRODUCTION

Under authority of the Comprehensive Environmental Response, Compensation and Liability Act of 1980 (CERCLA) and the Superfund Amendments and Reauthorization Act of 1986 (SARA), a Preliminary Assessment (PA) was conducted at the ZY - Waycross Army Airfield, Waycross, Ware County, Georgia. The purpose of this investigation was to collect sufficient information to assess the threat posed to human health and the environment. Determining the need for additional investigations included a review of available file information, a comprehensive target survey and an on- and off-site reconnaissance.

2. SITE DESCRIPTION, OPERATIONAL HISTORY, AND WASTE CHARACTERISTICS

2.1 LOCATION

The ZY - Waycross Army Airfield is is currently known as the Waycross/Ware County Airport. It is located in Ware County, northwest of Waycross, between U.S. Highways No. 1 and No. 82. The airport is adjacent to an industrial park and also located next to the county prison. All these facilities are on property which was once owned by the DOD. [Reference 1] The geographic coordinates are N 31° 15' 00.0" latitude and W082° 23' 45.0" longitude.

2.2 SITE DESCRIPTION AND OPERATIONAL HISTORY

The Waycross Army Airfield is approximately 2,633.94 acres in the size, which consisted of 36.25 acres fee acquired by purchase, 2,533.35 acres acquired by lease, and avigation easements over 64.34 acres acquired from 1943-1946. [Reference 1] The facility is now an Industrial Park with approximately ten (10) industries and/or companies. [Reference 6]

2.3 WASTE CHARACTERISTICS

The Waycross Army Airfield housed underground fuel storage tanks possibly containing petroleum products or residues associated with an airplane fueling station. [Reference 1]

3. GROUNDWATER PATHWAY

The geological formations below the facility and surrounding area in descending order are as follows:

3.1 HYDROGEOLOGIC SETTING

The facility is located in the Coastal Plain physiographic provice district which is characterized by a wedge-shaped block of sediments consisting of alternating layers of sand, clay and limestone which dip and thicken toward the southeast. [Reference 2] Geologic units which underlie the faciity area include, in descending stratigraphic orders: undifferentiated post-Miocene rocks, the Hawthorn Group, the Suwannee Limestone and the Ocala Limestone. [Reference 3]

3.2 GROUNDWATER TARGETS

In the area of the facility, there are two major sources of groundwater: The surficial aquifer and the underlying Floridan Aquifer system. The surficial aquifer has an approximate thickness of 25 feet. Groundwater is recharged by precipitation. The surficial aquifer is separated from the Floridan Aquifer system by the confining clay layers within the Hawthorn Group. The clay layers within the Hawthron Group have an approximate thickness of 350 feet. The Floridan Aquifer system is contained in the permeable units in the Suwannee and the Ocala Limestones. The top of the Floridan Aquifer system is located at a depth of approximately 350 to 400 feet bls. Groundwater in the Floridan Aquifer system occurs under confined conditions. [Reference 2,3] The city of Waycross has 2 water systems: system #1 has three (3) wells into the Floridan Aquifer (depths of approximately 700 ft bls); system #2 has two (2) wells into the same Aquifer at the same depths. The water system serves approximately 15,000 people that make up the Waycross city limits. [Reference 6] There is no documentation to support the existence of private wells, but the entire population within the 4 mile radius target area is not on city water.

3.3 GROUNDWATER CONCLUSIONS

There is no supported documentation for groundwater contamination, however there is a potential to groundwater contamination. There is no private well count, however the city water system wells fall with the 4 miles radius target area. This system servers approximately 15,000 people.

4. SURFACE WATER PATHWAY

4.1 HYDROLOGIC SETTING

Ware County is located in the Coastal Plain Physiographic Provice. The area is underlain by an estimated 4575 feet thick sequence of stratified sediments including: sand, clay, and limestone deposited over an igneous and metamorphic rock complex. The area is relatively flat, extremely swampy and dips gently toward the east.[Reference 3] Runoff from the facility would flow easterly toward Kettle Creek. From Kettle Creek water flows nrotheasterly for approximately 3 miles and enters into the Satilla River which continues beyond the 15 mile target area. The net annual precipitation is 6 inches.

4.2 SURFACE WATER TARGETS

There are no surface water intakes within 15 miles of the target area. The Satilla river is used for recreational fishing and swimming[Reference 6]. The target area is the habitat for the bald eagle, the wood stork, the Bachman's Warbler, the red-cockaded woodpecker, and the Florida panther which are on the Endangered Species List.

4.3 SURFACE WATER CONCLUSIONS

There is observed release to surface water, however, due to the close proximity of the Kettle Creek and that the area of study is relatively flat, there is a potential to surface water contamination.

5 SOIL EXPOSURE AND AIR PATHWAYS

The site is located approximately 2 miles northwest of downtown Waycross which is a moderately small community. The nearest resident is approximately .5 mile of the site. Access restrictions to the suspected contaminate source, if any, are undetermined at this time. There is no documentation of stressed vegetation.

6 CONCLUSIONS/RECOMMENDATIONS

The site was analyzed based on waste quantity scores of 18 (1 to 50,000 gallons) and 32 (50,001 to 5 million gallons) of which neither score was greater than or equal to 28.5. Based on the infomation gathered -- the lack of surface water targets, the lack of private drinking water wells -- I recommend that the Waycross Army Airfield receive a No Further Remedial Action Planned (NFRAP) disposition.

REFERENCES

REFERENCES

1. Defense Environmental Restoration Program for Formerly Used Sites Inventory Project Report, Project No. I04GA059200.

2. National Water Summary 1984, Hydrologic Events, Selected Water-Quality Trends, and Ground-Water Resources, United States Geological Survey Water-Supply 2275.

3. A Revision of the Lithostratigraphic Units of the Coastal Plain of Georgia, The Miocene Through Holocene, 1988, Bulletin 104.

4. Hydrogeologic Framework of the Floridan Aquifer System in Florida and in Parts of Georgia, Alabama, and South Carolina, Regional Aquifer-System Analysis, U.S. Geological Survey Professional Paper 1403-B.

5. Endangered and Threatened Species of the Southeastern United States, United States Department of the Interior Fish and Wildlife Service, August 23, 1985.

6. Record of Telephone Conversation, Charles McClellan [City of Waycross Water Department] and Gerald Foree [EPA, Region IV, Site Assessment Section], September 22, 1994.

APPENDIX A

OMB Approval Number: 2050-0095
Approved for Use Through: 1/92

PA Scoresheets

Site Name: ZY - Waycross Army Airfield

CERCLIS ID No.: GAD984307942

Street Address. Hwy # 1 and # 82

City/State/Zip: Waycross, Ware Co, Ga

Investigator: Gerald F. Foree

Agency/Organization: EPA, Region IV

Street Address: 345 Courtland Street

City/State/Zip: Atlanta, Ga 30314

Date: September 28, 1994

INSTRUCTIONS FOR SCORESHEETS

Introduction

This scoresheets package functions as a self-contained workbook providing all of the basic tools to apply collected data and calculate a PA score. Note that a computerized scoring tool, "PA-Score," is also available from EPA (Office of Solid Waste and Emergency Response, Directive 9345.1-11). The scoresheets provide space to:

- Record information collected during the PA
- Indicate references to support information
- Select and assign values ("scores") for factors
- Calculate pathway scores
- Calculate the site score

Do not enter values or scores in shaded areas of the scoresheets. You are encouraged to write notes on the scoresheets and especially on the Criteria Lists. On scoresheets with a reference column, indicate a number corresponding to attached sources of information or pages containing rationale for hypotheses; attach to the scoresheets a numbered list of these references. Evaluate all four pathways. Complete all Criteria Lists, scoresheets, and tables. Show calculations, as appropriate. If scoresheets are photocopy reproduced, copy and submit the numbered pages (right-side pages) only.

GENERAL INFORMATION

Site Description and Operational History: Briefly describe the site and its operating history. Provide the site name, owner/operator, type of facility and operations, size of property, active or inactive status, and years of waste generation. Summarize waste treatment, storage, or disposal activities that have or may have occurred at the site; note also if these activities are documented or alleged. Identify probable source types and prior spills. Summarize highlights of previous investigations.

Probable Substances of Concern: List hazardous substances that have or may have been stored, handled, or disposed at the site, based on your knowledge of site operations. Identify the sources to which the substances may be related. Summarize any existing analytical data concerning hazardous substances detected onsite, in releases from the site, or at targets.

GENERAL INFORMATION

Site Description and Operational History:

The Waycross Army Airfield is approximately 2,633.94 acres in the size, which consisted of 36.25 acres fee acquired by purchase, 2,533.35 acres acquired by lease, and avigation easements over 64.34 acres acquired from 1943-1946. [Reference 1] The facility is now an Industrial Park with approximately ten (10) industries and/or companies. [Reference 6]

Probable Substances of Concern:
(Previous investigations, analytical data)

GENERAL INFORMATION (continued)

Site Sketch: Prepare a sketch of the site (freehand is acceptable). Indicate all pertinent features of the site and nearby environs, including: waste sources, buildings, residences, access roads, parking areas, drainage patterns, water bodies, vegetation, wells, sensitive environments, etc.

Site Sketch:
(Show all pertinent features, indicate sources and closest targets, indicate north)

SOURCE EVALUATION

- Number and name each source (e.g., 1. East Drum Storage Area, 2. Sludge Lagoon, 3. Battery Pile).
- Identify source type according to the list below.
- Describe the physical character of each source (e.g., dimensions, contents, waste types, containment, operating history).
- Show waste quantity (WQ) calculations for each source for appropriate tiers. Refer to instructions opposite page 5 and PA Tables 1a and 1b. Identify waste quantity tier and waste characteristics (WC) factor category score (for a site with a single source, according to PA Table 1a). Determine WC from PA Table 1b for the sum of source WQs for a multiple-source site.
- Attach additional sheets if necessary.
- Determine the site WC factor category score and record at the bottom of the page.

Source Type Descriptions

Landfill: an engineered (by excavation or construction) or natural hole in the ground into which wastes have been disposed by backfilling, or by contemporaneous soil deposition with waste disposal, covering wastes from view.

Surface Impoundment: a topographic depression, excavation, or diked area, primarily formed from earthen materials (lined or unlined) and designed to hold accumulated liquid wastes, wastes containing free liquids, or sludges that were not backfilled or otherwise covered during periods of deposition; depression may be dry if deposited liquid has evaporated, volatilized or leached, or wet with exposed liquid; structures that may be more specifically described as lagoon pond, aeration pit, settling pond, tailings pond, sludge pit, etc.; also a surface impoundment that has been covered with soil after the final deposition of waste materials (i.e., buried or backfilled).

Drums: portable containers designed to hold a standard 55-gallon volume of wastes.

Tanks and Non-Drum Containers: any stationary device, designed to contain accumulated wastes, constructed primarily of fabricated materials (such as wood, concrete, steel, or plastic) that provide structural support; any portable or mobile device in which waste is stored or otherwise handled.

Contaminated Soil: soil onto which available evidence indicates that a hazardous substance was spilled, spread, disposed, or deposited.

Pile: any non-containerized accumulation above the ground surface of solid, non-flowing wastes; includes open dumps. Some types of piles are: Chemical Waste Pile -- consists primarily of discarded chemical products, by-products, radioactive wastes, or used or unused feedstocks; Scrap Metal or Junk Pile -- consists primarily of scrap metal or discarded durable goods such as appliances, automobiles, auto parts, or batteries, composed of materials suspected to contain or have contained a hazardous substance; Tailings Pile -- consists primarily of any combination of overburden from a mining operation and tailings from a mineral mining, beneficiation, or processing operation; Trash Pile -- consists primarily of paper, garbage, or discarded non-durable goods which are suspected to contain or have contained a hazardous substance.

Land Treatment: landfarming or other land treatment method of waste management in which liquid wastes or sludges are spread over land and tilled, or liquids are injected at shallow depths into soils.

Other: a source that does not fit any of the descriptions above; examples include contaminated building, ground water plume with no identifiable source, storm drain, dry well, and injection well.

SOURCE EVALUATION

Source No.: 1A	Source Name: Tanks	Source Waste Quantity (WQ) Calculations:
Source Description: $\leq$ 50,000 gallons ∴ WC = 18		

Source No.: 1B	Source Name: Tanks	Source Waste Quantity (WQ) Calculations:
Source Description: > 50,000 but < 5 million gallons ∴ WC = 32		

Source No.:	Source Name:	Source Waste Quantity (WQ) Calculations:
Source Description:		

Site WC:

WASTE CHARACTERISTICS (WC) SCORES

WC, based on waste quantity, may be determined by one or all of four measures called "tiers": constituent quantity, wastestream quantity, source volume, and source area. PA Table 1a (page 5) is divided into these four tiers. The amount and detail of information available determine which tier(s) to use for each source. For each source, evaluate waste quantity by as many of the tiers as you have information to support, and select the result that gives you the highest WC score. If minimal, incomplete, or no information is available regarding waste quantity, assign a WC score of 18 (minimum).

PA Table 1a has 6 columns: column 1 indicates the quantity tier; column 2 lists source types for the four tiers; columns 3, 4, and 5 provide ranges of waste amount for <u>sites with only one source</u>, which correspond to WC scores at the top of the columns (18, 32, or 100); column 6 provides formulas to obtain source waste quantity (WQ) values at <u>sites with multiple sources</u>.

To determine WC for sites with only one source:

1. *Identify source type (see descriptions opposite page 4).*
2. *Examine all waste quantity data available.*
3. *Estimate the mass and/or dimensions of the source.*
4. *Determine which quantity tiers to use based on available source information.*
5. *Convert source measurements to appropriate units for each tier you can evaluate for the source.*
6. *Identify the range into which the total quantity falls for each tier evaluated (PA Table 1a).*
7. *Determine the highest WC score obtained for any tier (18, 32, or 100, at top of PA Table 1a columns 3, 4, and 5, respectively).*
8. *Use this WC score for all pathways.* *

To determine WC for sites with multiple sources:

1. *Identify each source type (see descriptions opposite page 4).*
2. *Examine all waste quantity data available for each source.*
3. *Estimate the mass and/or dimensions of each source.*
4. *Determine which quantity tiers to use for each source based on the available information.*
5. *Convert source measurements to appropriate units for each tier you can evaluate for each source.*
6. *For each source, use the formulas in column 6 of PA Table 1a to determine the WQ value for each tier that can be evaluated. The highest WQ value obtained for any tier is the WQ value for the source.*
7. *Sum the WQ values for all sources to get the site WQ total.*
8. *Use the site WQ total from step 7 to assign the WC score from PA Table 1b.*
9. *Use this WC score for all pathways.* *

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* The WC score is considered in all four pathways. However, if a primary target is identified for the ground water, surface water, or air migration pathway, assign the determined WC or a score of 32, whichever is <u>greater</u>, as the WC score for that pathway.

PA TABLE 1: WASTE CHARACTERISTICS (WC) SCORES

PA Table 1a: WC Scores for Single Source Sites and Formulas for Multiple Source Sites

TIER	SOURCE TYPE	SINGLE SOURCE SITES (assigned WC scores)			MULTIPLE SOURCE SITES
		WC = 18	*WC = 32*	*WC = 100*	Formula for Assigning Source WQ Values
CONSTITUENT	N/A	≤100 lb	>100 to 10,000 lb	>10,000 lb	*lb ÷ 1*
WASTESTREAM	N/A	≤500,000 lb	>500,000 to 50 million lb	>50 million lb	*lb ÷ 5,000*
VOLUME	Landfill	≤6.75 million ft^3 ≤250,000 yd^3	>6.75 million to 675 million ft^3 >250,000 to 25 million yd^3	>675 million ft^3 >25 million yd^3	*ft^3 ÷ 67,500* *yd^3 ÷ 2,500*
	Surface impoundment	≤6,750 ft^3 ≤250 yd^3	>6,750 to 675,000 ft^3 >250 to 25,000 yd^3	>675,000 ft^3 >25,000 yd^3	*ft^3 ÷ 67.5* *yd^3 ÷ 2.5*
	Drums	≤1,000 drums	>1,000 to 100,000 drums	>100,000 drums	*drums ÷ 10*
	Tanks and non-drum containers	≤50,000 gallons	>50,000 to 5 million gallons	>5 million gallons	*gallons ÷ 500*
	Contaminated soil	≤6.75 million ft^3 ≤250,000 yd^3	>6.75 million to 675 million ft^3 >250,000 to 25 million yd^3	>675 million ft^3 >25 million yd^3	*ft^3 ÷ 67,500* *yd^3 ÷ 2,500*
	Pile	≤6,750 ft^3 ≤250 yd^3	>6,750 to 675,000 ft^3 >250 to 25,000 yd^3	>675,000 ft^3 >25,000 yd^3	*ft^3 ÷ 67.5* *yd^3 ÷ 2.5*
	Other	≤6,750 ft^3 ≤250 yd^3	>6,750 to 675,000 ft^3 >250 to 25,000 yd^3	>675,000 ft^3 >25,000 yd^3	*ft^3 ÷ 67.5* *yd^3 ÷ 2.5*
AREA	Landfill	≤340,000 ft^2 ≤7.8 acres	>340,000 to 34 million ft^2 >7.8 to 780 acres	>34 million ft^2 >780 acres	*ft^2 ÷ 3,400* *acres ÷ 0.078*
	Surface impoundment	≤1,300 ft^2 ≤0.029 acres	>1,300 to 130,000 ft^2 >0.029 to 2.9 acres	>130,000 ft^2 >2.9 acres	*ft^2 ÷ 13* *acres ÷ 0.00029*
	Contaminated soil	≤3.4 million ft^2 ≤78 acres	>3.4 million to 340 million ft^2 >78 to 7,800 acres	>340 million ft^2 >7,800 acres	*ft^2 ÷ 34,000* *acres ÷ 0.78*
	Pile*	≤1,300 ft^2 ≤0.029 acres	>1,300 to 130,000 ft^2 >0.029 to 2.9 acres	>130,000 ft^2 >2.9 acres	*ft^2 ÷ 13* *acres ÷ 0.00029*
	Land treatment	≤27,000 ft^2 ≤0.62 acres	>27,000 to 2.7 million ft^2 >0.62 to 62 acres	>2.7 million ft^2 >62 acres	*ft^2 ÷ 270* *acres ÷ 0.0062*

1 ton = 2,000 lb = 1 yd^3 = 4 drums = 200 gallons

* Use area of land surface under pile, not surface area of pile.

PA Table 1b: WC Scores for Multiple Source Sites

WQ Total	*WC Score*
>0 to 100	18
>100 to 10,000	32
>10,000	100

GROUND WATER PATHWAY

Ground Water Use Description: Provide information on ground water use in the vicinity. Present the general stratigraphy, aquifers used, and distribution of private and municipal wells.

Calculations for Drinking Water Populations Served by Ground Water: Provide populations from private wells and municipal supply systems in each distance category. Show apportionment calculations for blended supply systems.

GROUND WATER PATHWAY
GROUND WATER USE DESCRIPTION

Describe Ground Water Use Within 4-miles of the Site:
(Describe stratigraphy, information on aquifers, municipal and/or private wells)

In the area of the facility, there are two major sources of groundwater: The surficial aquifer and the underlying Floridan Aquifer system. The surficial aquifer has an approximate thickness of 25 feet. Groundwater is recharged by precipitation. The surficial aquifer is separated from the Floridan Aquifer system by the confining clay layers within the Hawthorn Group. The clay layers within the Hawthron Group have an approximate thickness of 350 feet. The Floridan Aquifer system is contained in the permeable units in the Suwannee and the Ocala Limestones. The top of the Floridan Aquifer system is located at a depth of approximately 350 to 400 feet bls. Groundwater in the Floridan Aquifer system occurs under confined conditions. **[Reference 2,3]** The city of Waycross has 2 water systems: system #1 has three (3) wells into the Floridan Aquifer (depths of approximately 700 ft bls); system #2 has two (2) wells into the same Aquifer at the same depths. The water system serves approximately 15,000 people that make up the Waycross city limits. **[Reference 6]** There is no documentation to support the existence of private wells, but the entire population within the 4 mile radius target area is not on city water.

Calculations for Drinking Water Populations Served by Ground Water:

GROUND WATER PATHWAY CRITERIA LIST

This "Criteria List" helps guide the process of developing hypotheses concerning the occurrence of a suspected release and the exposure of specific targets to a hazardous substance. The check-boxes record your professional judgment in evaluating these factors. Answers to all of the listed questions may not be available during the PA. Also, the list is not all-inclusive; if other criteria help shape your hypotheses, list them at the bottom of the page or attach an additional page.

The "Suspected Release" section identifies several site, source, and pathway conditions that could provide insight as to whether a release from the site is likely to have occurred. If a release is suspected, use the "Primary Targets" section to evaluate conditions that may help identify targets likely to be exposed to a hazardous substance. Record responses for the well that you feel has the highest probability of being exposed to a hazardous substance. You may use this section of the chart more than once, depending on the number of targets you feel may be considered "primary."

Check the boxes to indicate a "yes," "no," or "unknown" answer to each question. If you check the "Suspected Release" box as "yes," make sure you assign a Likelihood of Release value of 550 for the pathway.

GROUND WATER PATHWAY CRITERIA LIST

SUSPECTED RELEASE

Yes	No	Unk	
☐	☐	☒	Are sources poorly contained?
☒	☐	☐	Is the source a type likely to contribute to ground water contamination (e.g., wet lagoon)?
☐	☐	☒	Is waste quantity particularly large?
☐	☒	☐	Is precipitation heavy?
☐	☒	☐	Is the infiltration rate high?
☐	☒		Is the site located in an area of karst terrain?
☐	☒	☐	Is the subsurface highly permeable or conductive?
☐	☒	☐	Is drinking water drawn from a shallow aquifer?
☐	☐	☒	Are suspected contaminants highly mobile in ground water?
☐	☒	☐	Does analytical or circumstantial evidence suggest ground water contamination?
☐	☒		Other criteria? ______________________
☐	☒		**SUSPECTED RELEASE?**

PRIMARY TARGETS

Yes	No	Unk	
☒	☐	☐	Is any drinking water well nearby?
☐	☒	☐	Has any nearby drinking water well been closed?
☐	☒	☐	Has any nearby drinking water user reported foul-tasting or foul-smelling water?
☐	☒	☐	Does any nearby well have a large drawdown or high production rate?
☐	☐	☒	Is any drinking water well located between the site and other wells that are suspected to be *exposed to a hazardous substance?*
☐	☒	☐	Does analytical or circumstantial evidence *suggest contamination at a drinking water well?*
☐	☐	☒	Does any drinking water well warrant sampling?
☐	☒		*Other criteria?* ______________________
☐	☒		**PRIMARY TARGET(S) IDENTIFIED?**

Summarize the rationale for Suspected Release (attach an *additional page if necessary*):

Summarize the rationale for Primary Targets (attach an *additional page if necessary*):

GROUND WATER PATHWAY SCORESHEET

<u>Pathway Characteristics</u>

Answer the questions at the top of the page. Refer to the Ground Water Pathway Criteria List (page 7) to hypothesize whether you suspect that a hazardous substance associated with the site has been released to ground water. Record depth to aquifer (in feet): the difference between the deepest occurrence of a hazardous substance and the depth of the top of the shallowest aquifer at (or as near as possible) to the site. Note whether the site is in karst terrain (characterized by abrupt ridges, sink holes, caverns, springs, disappearing streams). Record the distance (in feet) from any source to the nearest well used for drinking water.

<u>Likelihood of Release (LR)</u>

1. **Suspected Release:** Hypothesize based on professional judgment guided by the Ground Water Pathway Criteria List (page 7). If you suspect a release to ground water, use only Column A for this pathway and do not evaluate factor 2.

2. **No Suspected Release:** If you do not suspect a release, determine score based on depth to aquifer or whether the site is in an area of karst terrain. If you do not suspect a release to ground water, use only Column B to score this pathway.

<u>Targets (T)</u>

This factor category evaluates the threat to populations obtaining drinking water from ground water. To apportion populations served by blended drinking water supply systems, determine the percentage of population served by each well based on its production.

3. **Primary Target Population:** Evaluate populations served by all drinking water wells that you suspect have been exposed to a hazardous substance released from the site. Use professional judgment guided by the Ground Water Pathway Criteria List (page 7) to make this determination. In the space provided, enter the population served by any wells you suspect have been exposed to a hazardous substance from the site. If only the number of residences is known, use the average county residents per household (rounded up to the next integer) to determine population served. Multiply the population by 10 to determine the Primary Target Population score. Note that if you do not suspect a release, there can be no primary target population.

4. **Secondary Target Population:** Evaluate populations served by all drinking water wells within 4 miles that you do not suspect have been exposed to a hazardous substance. Use PA Table 2a or 2b (for wells drawing from non-karst and karst aquifers, respectfully) (page 9). If only the number of residences is known, use the average county residents per household (rounded to the nearest integer) to determine population served. Circle the assigned value for the population in each distance category and enter it in the column on the far-right side of the table. Sum the far-right column and enter the total as the Secondary Target Population factor score.

5. **Nearest Well** represents the threat posed to the drinking water well that is most likely to be exposed to a hazardous substance. If you have identified a primary target population, enter 50. Otherwise, assign the score from PA Table 2a or 2b for the closest distance category with a drinking water well population.

6. **Wellhead Protection Area (WHPA):** WHPAs are special areas designated by States for protection under Section 1428 of the Safe Drinking Water Act. Local/State and EPA Regional water officials can provide information regarding the location of WHPAs.

7. **Resources:** A score of 5 can generally be assigned as a default measure. Assign zero only if ground water within 4 miles has no resource use.

Sum the target scores in Column A (Suspected Release) or Column B (No Suspected Release).

<u>Waste Characteristics (WC)</u>

8. **Waste Characteristics:** Score is assigned from page 4. However, if you have identified any primary target for ground water, assign either the score calculated on page 4 or a score of 32, whichever is greater.

<u>Ground Water Pathway Score:</u> Multiply the scores for LR, T, and WC. Divide the product by 82,500. Round the result to the nearest integer. If the result is greater than 100, assign 100.

GROUND WATER PATHWAY SCORESHEET

Pathway Characteristics	
Do you suspect a release (see Ground Water Pathway Criteria List, page 7)?	Yes ___ No ___
Is the site located in karst terrain?	Yes ___ No ___
Depth to aquifer:	________ ft
Distance to the nearest drinking water well:	________ ft

LIKELIHOOD OF RELEASE	A *Suspected Release*	B *No Suspected Release*	*References*
1. SUSPECTED RELEASE: If you suspect a release to ground water (see page 7), assign a score of 550. Use only column A for this pathway.	(550)		______
2. NO SUSPECTED RELEASE: If you do not suspect a release to ground water, and the site is in karst terrain or the depth to aquifer is 70 feet or less, assign a score of 500; otherwise, assign a score of 340. Use only column B for this pathway.		(500 or 340) 340	______
LR =		340	

TARGETS	A	B	*References*
3. PRIMARY TARGET POPULATION: Determine the number of people served by drinking water wells that you suspect have been exposed to a hazardous substance from the site (see Ground Water Pathway Criteria List, page 7). ______ people x 10 =			______
4. SECONDARY TARGET POPULATION: Determine the number of people served by drinking water wells that you do NOT suspect have been exposed to a hazardous substance from the site, and assign the total population score from PA Table 2. Are any wells part of a blended system? Yes ___ No ___ If yes, attach a page to show apportionment calculations.		148	______
5. NEAREST WELL: If you have identified a primary target population for ground water, assign a score of 50; otherwise, assign the Nearest Well score from PA Table 2. If no drinking water wells exist within 4 miles, assign a score of zero.	(50, 20, 10, 8, 5, 3, 2, or 0)	(20, 10, 8, 5, 3, 2, or 0) 20	______
6. WELLHEAD PROTECTION AREA (WHPA): If any source lies within or above a WHPA, or if you have identified any primary target well within a WHPA, assign a score of 20; assign 5 if neither condition holds but a WHPA is present within 4 miles; otherwise assign zero.	(20, 5, or 0)	(20, 5, or 0) 0	______
7. RESOURCES	(5 or 0)	(5 or 0) 5	______
T =		173	

WASTE CHARACTERISTICS	A	B
8. A. If you have identified any primary target for ground water, assign the waste characteristics score calculated on page 4, or a score of 32, whichever is GREATER; do not evaluate part B of this factor.	(100 or 32)	
B. If you have NOT identified any primary target for ground water, assign the waste characteristics score calculated on page 4.	(100, 32, or 18)	(100, 32, or 18) (1A) (1B) 32/18
WC =		32/18

GROUND WATER PATHWAY SCORE: $\frac{LR \times T \times WC}{82{,}500}$ (subject to a maximum of 100) 22.8 / 12.8

PA TABLE 2: VALUES FOR SECONDARY GROUND WATER TARGET POPULATIONS

PA Table 2a: Non-Karst Aquifers

Distance from Site	Population	Nearest Well (choose highest)	Population Served by Wells Within Distance Category: 1 to 10	11 to 30	31 to 100	101 to 300	301 to 1,000	1,001 to 3,000	3,001 to 10,000	10,001 to 30,000	30,001 to 100,000	Greater than 100,000	Population Value
0 to ¼ mile	≤ 10	20	1	2	5	16	52	163	521	1,633	5,214	16,325	1
> ¼ to ½ mile	1,000	18	1	1	3	10	32	101	323	1,012	3,233	10,121	32
> ½ to 1 mile	2,000	9	1	1	2	5	17	52	167	522	1,668	5,224	52
> 1 to 2 miles	3,000	5	1	1	1	3	9	29	94	294	939	2,938	29
> 2 to 3 miles	2,000	3	1	1	1	2	7	21	68	212	678	2,122	21
> 3 to 4 miles	2,000	2	1	1	1	1	4	13	42	131	417	1,306	13
	Nearest Well =	20										Score =	148

PA Table 2b: Karst Aquifers

Distance from Site	Population	Nearest Well (use 20 for karst)	Population Served by Wells Within Distance Category: 1 to 10	11 to 30	31 to 100	101 to 300	301 to 1,000	1,001 to 3,000	3,001 to 10,000	10,001 to 30,000	30,001 to 100,000	Greater than 100,000	Population Value
0 to ¼ mile		20	1	2	5	16	52	163	521	1,633	5,214	16,325	
> ¼ to ½ mile		20	1	1	3	10	32	101	323	1,012	3,233	10,121	
> ½ to 1 mile		20	1	1	3	8	26	82	261	816	2,607	8,162	
> 1 to 2 miles		20	1	1	3	8	26	82	261	816	2,607	8,162	
> 2 to 3 miles		20	1	1	3	8	26	82	261	816	2,607	8,162	
> 3 to 4 miles		20	1	1	3	8	26	82	261	816	2,607	8,162	
	Nearest Well =											Score =	

SURFACE WATER PATHWAY

Migration Route Sketch: Sketch the surface water migration pathway (freehand is acceptable) illustrating the drainage route and identifying water bodies, probable point of entry, flows, and targets.

There are no surface water intakes within 15 miles of the target area. The Satilla river is used for recreational fishing and swimming[**Reference 6**]. The target area is the habitat for the bald eagle, the wood stork, the Bachman's Warbler, the red-cockaded woodpecker, and the Florida panther which are on the Endangered Species List.

SURFACE WATER PATHWAY
MIGRATION ROUTE SKETCH

Suface Water Migration Route Sketch:
(include runoff route, probable point of entry, 15-mile target distance limit, intakes, fisheries, and sensitive environments)

SURFACE WATER PATHWAY CRITERIA LIST

This "Criteria List" helps guide the process of developing hypotheses concerning the occurrence of a suspected release and the exposure of specific targets to a hazardous substance. The check-boxes record your professional judgment in evaluating these factors. Answers to all of the listed questions may not be available during the PA. Also, the list is not all-inclusive; if other criteria help shape your hypotheses, list them at the bottom of the page or attach an additional page.

The "Suspected Release" section identifies several site, source, and pathway conditions that could provide insight as to whether a release from the site is likely to have occurred. If a release is suspected, use the "Primary Targets" section to guide you through evaluation of some conditions that may help identify targets likely to be exposed to a hazardous substance. Record responses for the target that you feel has the highest probability of being exposed to a hazardous substance. You may use this section of the chart more than once, depending on the number of targets you feel may be considered "primary."

Check the boxes to indicate a "yes," "no," or "unknown" answer to each question. If you check the "Suspected Release" box as "yes," make sure you assign a Likelihood of Release value of 550 for the pathway.

If the distance to surface water is greater than 2 miles, do not evaluate the surface water migration pathway. Document the source of information in the text boxes below the surface water criteria list.

SURFACE WATER PATHWAY CRITERIA LIST

SUSPECTED RELEASE

Yes	No	Unk	
☒	☐	☐	Is surface water nearby?
☐	☐	☒	Is waste quantity particularly large?
☐	☐	☒	Is the drainage area large?
☐	☒	☐	Is rainfall heavy?
☐	☒	☐	Is the infiltration rate low?
☐	☐	☒	Are sources poorly contained or prone to runoff or flooding?
☐	☒	☐	Is a runoff route well defined (e.g., ditch or channel leading to surface water)?
☐	☐	☒	Is vegetation stressed along the probable run-off route?
☐	☐	☒	Are sediments or water unnaturally discolored?
☐	☐	☒	Is wildlife unnaturally absent?
☐	☒	☐	Has deposition of waste into surface water been observed?
☐	☐	☒	Is ground water discharge to surface water likely?
☐	☒	☐	Does analytical or circumstantial evidence suggest surface water contamination?
☐	☒		Other criteria? __________
☐	☒		**SUSPECTED RELEASE?**

Summarize the rationale for Suspected Release (attach an additional page if necessary):

PRIMARY TARGETS

Yes	No	Unk	
☒	☐	☐	Is any target nearby? If yes: ☐ Drinking water intake ☐ Fishery ☒ Sensitive environment
☐	☒	☐	Has any intake, fishery, or recreational area been closed?
☐	☒	☐	Does analytical or circumstantial evidence suggest surface water contamination at or downstream of a target?
☐	☒	☐	Does any target warrant sampling? If yes: ☐ Drinking water intake ☐ Fishery ☐ Sensitive environment
☐	☒		Other criteria? __________
☐	☒		**PRIMARY INTAKE(S) IDENTIFIED?**
☐	☒		**PRIMARY FISHERY(IES) IDENTIFIED?**
☒	☐		**PRIMARY SENSITIVE ENVIRONMENT(S) IDENTIFIED?**

Summarize the rationale for Primary Targets (attach an additional page if necessary):

SURFACE WATER PATHWAY LIKELIHOOD OF RELEASE AND DRINKING WATER THREAT SCORESHEET

Pathway Characteristics

The surface water pathway includes three threats: Drinking Water Threat, Human Food Chain Threat, and Environmental Threat. Answer the questions at the top of the page. Refer to the Surface Water Pathway Criteria List (page 11) to hypothesize whether you suspect that a hazardous substance associated with the site has been released to surface water. Record the distance to surface water (the shortest overland drainage distance from a source to a surface water body). Record the flood frequency at the site (e.g., 100-yr, 200-yr). If the site is located in more than one floodplain, use the most frequent flooding event. Identify surface water use(s) along the surface water migration path and their distance(s) from the site.

Likelihood of Release (LR)

1. Suspected Release: Hypothesize based on professional judgment guided by the Surface Water Pathway Criteria List (page 11). If you suspect a release to surface water, use only Column A for this pathway and do not evaluate factor 2.

2. No Suspected Release: If you do not suspect a release, determine score based on the shortest overland drainage distance from a source to a surface water body. If distance to surface water is 2,500 feet or less, assign a score of 500. If distance to surface water is greater than 2,500 feet, determine score based on flood frequency. If you do not suspect a release to surface water, use only Column B to score this pathway.

Drinking Water Threat Targets (T)

3. List all drinking water intakes on downstream surface water bodies along the surface water migration path. Record the intake name, the type of water body on which the intake is located, the flow of the water body, and the number of people served by the intake (apportion the population if part of a blended system).

4. Primary Target Population: Evaluate populations served by all drinking water intakes that you suspect have been exposed to a hazardous substance released from the site. Use professional judgment guided by the Surface Water Pathway Criteria List (page 11) to make this determination. In the space provided, enter the population served by all intakes you suspect have been exposed to a hazardous substance from the site. If only the number of residences is known, use the average county residents per household (rounded up to the next integer) to determine population served. Multiply by 10 to determine the Primary Target Population score. Remember, if you do not suspect a release, there can be no primary target population.

5. Secondary Target Population: Evaluate populations served by all drinking water intakes within the target distance limit that you do not suspect have been exposed to a hazardous substance. Use PA Table 3 (page 13) and enter the population served by intakes for each flow category. If only the number of residences is known, use the average county residents per household (rounded to the nearest integer) to determine population served. Circle the assigned value for the population in each flow category and enter it in the column on the far-right side of the table. Sum the far-right column and enter the total as the Secondary Target Population factor score.

Gauging station data for many surface water bodies are available from USGS or other sources. In the absence of gauging station data, estimate flow using the list of surface water body types and associated flow categories in PA Table 4 (page 13). The flow for lakes is determined by the sum of flows of streams entering or leaving the lake. Note that the flow category "mixing zone of quiet flowing rivers" is limited to 3 miles from the probable point of entry.

6. Nearest Intake represents the threat posed to the drinking water intake that is most likely to be exposed to a hazardous substance. If you have identified a primary target population, enter 50. Otherwise, assign the score from PA Table 3 (page 13) for the lowest-flowing water body on which there is an intake.

7. Resources: A score of 5 can generally be assigned as a default measure. Assign zero only if surface water within the target distance limit has no resource use.

Sum the target scores in Column A (Suspected Release) or Column B (No Suspected Release).

SURFACE WATER PATHWAY
LIKELIHOOD OF RELEASE AND DRINKING WATER THREAT SCORESHEET

Pathway Characteristics	
Do you suspect a release (see Surface Water Pathway Criteria List, page 11)?	Yes ___ No ___
Distance to surface water:	______ ft
Flood frequency:	______ yrs
What is the downstream distance to the nearest drinking water intake? ______ miles	
Nearest fishery? ______ miles Nearest sensitive environment? ______ miles	

LIKELIHOOD OF RELEASE

	A *Suspected Release*	B *No Suspected Release*	*References*
1. SUSPECTED RELEASE: If you suspect a release to surface water (see page 11), assign a score of 550. Use only column A for this pathway.	(550)		
2. NO SUSPECTED RELEASE: If you do not suspect a release to surface water, use the table below to assign a score based on distance to surface water and flood frequency. Use only column B for this pathway.		(500, 400, 300, or 100) 400	
LR =	(550)	(500, 400, 300, or 100)	

Distance to surface water ≤ 2,500 feet	*500*
Distance to surface water > 2,500 feet, and	
Site in annual or 10-year floodplain	*500*
Site in 100-year floodplain	*400*
Site in 500-year floodplain	*300*
Site outside 500-year floodplain	*100*

DRINKING WATER THREAT TARGETS

3. Record the water body type, flow (if applicable), and number of people served by each drinking water intake within the target distance limit. If there is no drinking water intake within the target distance limit, factors 4, 5, and 6 each receive zero scores.

Intake Name	*Water Body Type*	*Flow*	*People Served*
______	______	______ cfs	______
______	______	______ cfs	______
______	______	______ cfs	______

	A *Suspected Release*	B *No Suspected Release*	*References*
4. PRIMARY TARGET POPULATION: If you suspect any drinking water intake listed above has been exposed to a hazardous substance from the site (see Surface Water Pathway Criteria List, page 11), list the intake name(s) and calculate the factor score based on the total population served. ______, ______, ______ people x 10 =			
5. SECONDARY TARGET POPULATION: Determine the number of people served by drinking water intakes that you do NOT suspect have been exposed to a hazardous substance from the site, and assign the total population score from PA Table 3. Are any intakes part of a blended system? Yes ___ No ___ If yes, attach a page to show apportionment calculations.		0	
6. NEAREST INTAKE: If you have identified a primary target population for the drinking water threat (factor 4), assign a score of 50; otherwise, assign the Nearest Intake score from PA Table 3. If no drinking water intake exists within the target distance limit, assign a score of zero.	(50, 20, 10, 2, 1, or 0)	(20, 10, 2, 1 or 0) 0	
7. RESOURCES	(5 or 0)	(5 or 0) 5	
T =		5	

PA TABLE 3: VALUES FOR SECONDARY SURFACE WATER TARGET POPULATIONS

Surface Water Body Flow (see PA Table 4)	*Population*	*Nearest Intake (choose highest)*	*Population Served by Intakes Within Flow Category* 1 to 30	31 to 100	101 to 300	301 to 1,000	1,001 to 3,000	3,001 to 10,000	10,001 to 30,000	30,001 to 100,000	100,001 to 300,000	300,001 to 1,000,000	Greater than 1,000,000	*Population Value*
<10 cfs	____	20	2	5	16	52	163	521	1,633	5,214	16,325	52,136	163,246	____
10 to 100 cfs	____	2	1	1	2	5	16	52	163	521	1,633	5,214	16,325	____
>100 to 1,000 cfs	____	1	0	0	1	1	2	5	16	52	163	521	1,633	____
>1,000 to 10,000 cfs	____	0	0	0	0	0	1	1	2	5	16	52	163	____
>10,000 cfs or Great Lakes	____	0	0	0	0	0	0	0	1	1	2	5	16	____
3-mile Mixing Zone	____	10	1	3	8	26	82	261	816	2,607	8,162	26,068	81,663	____

Nearest Intake = ____ **Score =** ____

PA TABLE 4: SURFACE WATER TYPE / FLOW CHARACTERISTICS WITH DILUTION WEIGHTS FOR SECONDARY SURFACE WATER SENSITIVE ENVIRONMENTS

Type of Surface Water Body — *Water Body Type*	*OR*	*Flow*	*Dilution Weight*
minimal stream		< 10 cfs	*1*
small to moderate stream		10 to 100 cfs	*0.1*
moderate to large stream		> 100 to 1,000 cfs	*N/A*
large stream to river		> 1,000 to 10,000 cfs	*N/A*
large river		> 10,000 cfs	*N/A*
3-mile mixing zone of quiet flowing streams or rivers		10 cfs or greater	*N/A*
coastal tidal water (harbors, sounds, bays, etc.), ocean, or Great Lakes		N/A	*N/A*

SURFACE WATER PATHWAY HUMAN FOOD CHAIN THREAT SCORESHEET

Likelihood of Release (LR)

LR is the same for all surface water pathway threats. Enter LR score from page 12.

Human Food Chain Threat Targets (T)

8. The only human food chain targets are fisheries. A fishery is an area of a surface water body from which food chain organisms are taken or could be taken for human consumption on a subsistence, sporting, or commercial basis. Food chain organisms include fish, shellfish, crustaceans, amphibians, and amphibious reptiles. Fisheries are delineated by changes in surface water body type (i.e., streams and rivers, lakes, coastal tidal waters, and oceans/Great Lakes) and whenever the flow characteristics of a stream or river change.

In the space provided, identify all fisheries within the target distance limit. Indicate the surface water body type and flow for each fishery. Gauging station flow data are available for many surface water bodies from USGS or other sources. In the absence of gauging station data, estimate flow using the list of surface water body types and associated flow categories in PA Table 4 (page 13). The flow for lakes is determined by the sum of flows of streams entering or leaving the lake. Note that, if there are no fisheries within the target distance limit, the Human Food Chain Threat Targets score is zero.

9. **Primary fisheries** are any fisheries within the target distance limit that you suspect have been exposed to a hazardous substance released from the site. Use professional judgment guided by the Surface Water Pathway Criteria List (page 11) to make this determination. If you identify any primary fisheries, list them in the space provided, enter 300 as the Primary Fisheries factor score, and do not evaluate Secondary Fisheries. Note that if you do not suspect a release, there can be no primary fisheries.

10. **Secondary fisheries** are fisheries that you do not suspect have been exposed to a hazardous substance. Evaluate this factor only if fisheries are present within the target distance limit, but none is considered a primary fishery.

A. If you suspect a release to surface water and have identified a secondary fishery but no primary fishery, assign a score of 210.

B. If you do not suspect a release, evaluate this factor based on flow. In the absence of gauging station flow data, estimate flow using the list of surface water body types and associated flow categories in PA Table 4 (page 13). Assign a Secondary Fisheries score from the table on the scoresheet using the lowest flow at any fishery within the target distance limit. (Dilution weight multiplier does not apply to PA evaluation of this factor.)

Sum the target scores in Column A (Suspected Release) or Column B (No Suspected Release).

HUMAN FOOD CHAIN THREAT SCORESHEET

LIKELIHOOD OF RELEASE		A Suspected Release	B No Suspected Release	References
Enter Surface Water Likelihood of Release score from page 12.	LR =	(550)	(500, 400, 300 or 100) 400	

HUMAN FOOD CHAIN THREAT TARGETS

8. Record the water body type and flow (if applicable) for each fishery within the target distance limit. If there is no fishery within the target distance limit, assign a Targets score of 0 at the bottom of the page.

Fishery Name	*Water Body Type*	*Flow*
		____cfs
		____cfs
		____cfs
		____cfs
		____cfs

9. PRIMARY FISHERIES: If you suspect any fishery listed above has been exposed to a hazardous substance from the site (see Surface Water Criteria List, page 11), assign a score of 300 and do not evaluate Factor 10. List the primary fisheries:

____________________, ____________________,
____________________, ____________________.

A (Suspected Release): (300)

10. SECONDARY FISHERIES

A. If you suspect a release to surface water and have identified a secondary fishery but no primary fishery, assign a score of 210.

A (Suspected Release): (210)

B. If you do not suspect a release, assign a Secondary Fisheries score from the table below using the lowest flow at any fishery within the target distance limit.

Lowest Flow	*Secondary Fisheries Score*
< 10 cfs	210
10 to 100 cfs	30
> 100 cfs, coastal tidal waters, oceans, or Great Lakes	12

B (No Suspected Release): (210, 30 or 12) 30

	A	B
T =	(300, 210 or 0)	(210, 30, 12 or 0) 30

SURFACE WATER PATHWAY ENVIRONMENTAL THREAT SCORESHEET

Likelihood of Release (LR)

LR is the same for all surface water pathway threats. Enter LR score from page 12.

Environmental Threat Targets (T)

11. PA Table 5 (page 16) lists sensitive environments for the Surface Water Pathway Environmental Threat. In the space provided, identify all sensitive environments located within the target distance limit. Indicate the surface water body type and flow at each sensitive environment. Gauging station flow data for many surface water bodies are available from USGS or other sources. In the absence of gauging station data, estimate flow using the list of surface water body types and associated flow categories in PA Table 4 (page 13). The flow for lakes is determined by the sum of flows of streams entering or leaving the lake. Note that if there are no sensitive environments within the target distance limit, the Environmental Threat Targets score is zero.

12. **Primary sensitive environments** are surface water sensitive environments within the target distance limit that you suspect have been exposed to a hazardous substance released from the site. Use professional judgment guided by the Surface Water Pathway Criteria List (page 11) to make this determination. If you identify any primary sensitive environments, list them in the space provided, enter 300 as the Primary Sensitive Environments factor score, and do not evaluate Secondary Sensitive Environments. Note that if you do not suspect a release, there can be no primary sensitive environments.

13. **Secondary sensitive environments** are surface water sensitive environments that you do not suspect have been exposed to a hazardous substance. Evaluate this factor only if surface water sensitive environments are present within the target distance limit, but none is considered a primary sensitive environment. Evaluate secondary sensitive environments based on flow.

- In the table provided, list all secondary sensitive environments on surface water bodies with flow of 100 cfs or less.

    1) Use PA Table 4 (page 13) to determine the appropriate dilution weight for each.

    2) Use PA Tables 5 and 6 (page 16) to determine the appropriate value for each sensitive environment type and for wetlands frontage.

    3) For a sensitive environment that falls into more than one of the categories in PA Table 5, sum the values for each type to determine the environment value (e.g., a wetland with 1.5 miles frontage (value of 50) that is also a critical habitat for a Federally designated endangered species (value of 100) would receive a total value of 150).

    4) For each sensitive environment, multiply the dilution weight by the environment type (or length of wetlands) value and record the product in the far-right column.

    5) Sum the values in the far-right column and enter the total as the Secondary Sensitive Environments score. Do not evaluate part B of this factor.

- If all secondary sensitive environments are on surface water bodies with flows greater than 100 cfs, assign 10 as the Secondary Sensitive Environments score.

Sum the target scores in Column A (Suspected Release) or Column B (No Suspected Release).

SURFACE WATER PATHWAY (continued)
ENVIRONMENTAL THREAT SCORESHEET

LIKELIHOOD OF RELEASE		A Suspected Release	B No Suspected Release	References
Enter Surface Water Likelihood of Release score from page 12.	LR =		400	

ENVIRONMENTAL THREAT TARGETS

11. Record the water body type and flow (if applicable) for each surface water sensitive environment within the target distance limit (see PA Tables 4 and 5). If there is no sensitive environment within the target distance limit, assign a Targets score of 0 at the bottom of the page.

Environment Name	Water Body Type	Flow
		cfs
		cfs
		cfs
		cfs
		cfs

12. PRIMARY SENSITIVE ENVIRONMENTS: If you suspect any sensitive environment listed above has been exposed to a hazardous substance from the site (see Surface Water Criteria List, page 11), assign a score of 300 and do not evaluate factor 13. List the primary sensitive environments:

______, ______,
______, ______.

13. SECONDARY SENSITIVE ENVIRONMENTS: If sensitive environments are present, but none is a primary sensitive environment, evaluate Secondary Sensitive Environments based on flow.

A. For secondary sensitive environments on surface water bodies with flows of 100 cfs or less, assign scores as follows, and do not evaluate part B of this factor:

Flow	Dilution Weight (PA Table 4)		Environment Type and Value (PA Tables 5 and 6)		Total
10 to 100 cfs	.1	x	100	=	10
cfs		x		=	
cfs		x		=	
cfs		x		=	
cfs		x		=	

	A	B
Sum =		10
B. If all secondary sensitive environments are located on surface water bodies with flows > 100 cfs, assign a score of 10.		10
T =		20

PA TABLE 5: SURFACE WATER AND AIR PATHWAY SENSITIVE ENVIRONMENTS VALUES

Sensitive Environment	*Assigned Value*
Critical habitat for Federally designated endangered or threatened species Marine Sanctuary National Park Designated Federal Wilderness Area Ecologically important areas identified under the Coastal Zone Wilderness Act Sensitive Areas identified under the National Estuary Program or Near Coastal Water Program of the Clean Water Act Critical Areas Identified under the Clean Lakes Program of the Clean Water Act (subareas in lakes or entire small lakes) National Monument (air pathway only) National Seashore Recreation Area National Lakeshore Recreation Area	100
Habitat known to be used by Federally designated or proposed endangered or threatened species National Preserve National or State Wildlife Refuge Unit of Coastal Barrier Resources System Federal land designated for the protection of natural ecosystems Administratively Proposed Federal Wilderness Area Spawning areas critical for the maintenance of fish/shellfish species within a river system, bay, or estuary Migratory pathways and feeding areas critical for the maintenance of anadromous fish species in a river system Terrestrial areas utilized for breeding by large or dense aggregations of vertebrate animals (air pathway) or semi-aquatic foragers (surface water pathway) National river reach designated as Recreational	75
Habitat known to be used by State designated endangered or threatened species Habitat known to be used by a species under review as to its Federal endangered or threatened status Coastal Barrier (partially developed) Federally designated Scenic or Wild River	50
State land designated for wildlife or game management State designated Scenic or Wild River State designated Natural Area Particular areas, relatively small in size, important to maintenance of unique biotic communities	25
State designated areas for protection/maintenance of aquatic life under the Clean Water Act	5
Wetlands	See PA Table 6 (Surface Water Pathway) or PA Table 9 (Air Pathway)

PA TABLE 6: SURFACE WATER PATHWAY WETLANDS FRONTAGE VALUES

Total Length of Wetlands	*Assigned Value*
Less than 0.1 mile	0
0.1 to 1 mile	25
Greater than 1 to 2 miles	50
Greater than 2 to 3 miles	75
Greater than 3 to 4 miles	100
Greater than 4 to 8 miles	150
Greater than 8 to 12 miles	250
Greater than 12 to 16 miles	350
Greater than 16 to 20 miles	450
Greater than 20 miles	500

SURFACE WATER PATHWAY WASTE CHARACTERISTICS, THREAT, AND PATHWAY SCORES

Waste Characteristics (WC)

14. **Waste Characteristics:** Score is assigned from page 4. However, if a primary target has been identified for any surface water threat, assign either the score calculated on page 4 or a score of 32, whichever is greater.

Surface Water Pathway Threat Scores

Fill in the matrix with the appropriate scores from the previous pages. To calculate the score for each threat: multiply the scores for LR, T, and WC; divide the product by 82,500; and round the result to the nearest integer. The Drinking Water Threat and Human Food Chain Threat are each subject to a maximum of 100. The Environmental Threat is subject to a maximum of 60. Enter the rounded threat scores in the far-right column.

Surface Water Pathway Score

Sum the individual threat scores to determine the Surface Water Pathway Score. If the sum is greater than 100, assign 100.

SURFACE WATER PATHWAY (concluded)
WASTE CHARACTERISTICS, THREAT, AND PATHWAY SCORE SUMMARY

WASTE CHARACTERISTICS	A *Suspected Release*	B *No Suspected Release*
14. A. If you have identified any primary target for surface water (pages 12, 14, or 15), assign the waste characteristics score calculated on page 4, or a score of 32, whichever is GREATER; do not evaluate part B of this factor.	(100 or 32)	
B. If you have NOT identified any primary target for surface water, assign the waste characteristics score calculated on page 4.	(100,32, or 18)	(100,32, or 18)
WC =		

SURFACE WATER PATHWAY THREAT SCORES

Threat	*Likelihood of Release (LR) Score (from page 12)*	*Targets (T) Score (pages 12, 14, 15)*	*Pathway Waste Characteristics (WC) Score (determined above)*	*Threat Score LR x T x WC / 82,500*
Drinking Water	400	5	32 / 18	(subject to a maximum of 100) .8 / .4
Human Food Chain	400	30	32 / 18	(subject to a maximum of 100) 4.7 / 2.6
Environmental	400	20	32 / 18	(subject to a maximum of 60) 3.1 / 1.7

SURFACE WATER PATHWAY SCORE (Drinking Water Threat + Human Food Chain Threat + Environmental Threat)	(subject to a maximum of 100) 8.6 / 4.7

SOIL EXPOSURE PATHWAY CRITERIA LIST

Areas of surficial contamination can generally be assumed. This "Criteria List" helps guide the process of developing a hypothesis concerning the exposure of specific targets to a hazardous substance at the site. Use the "Resident Population" section to evaluate site and source conditions that may help identify targets likely to be exposed to a hazardous substance. The check-boxes record your professional judgment. Answers to all of the listed questions may not be available during the PA. Also, the list is not all-inclusive; if other criteria help shape your hypothesis, list them at the bottom of the page or attach an additional page.

Check the boxes to indicate a "yes," "no," or "unknown" answer to each question.

SOIL EXPOSURE PATHWAY CRITERIA LIST	
SUSPECTED CONTAMINATION	***RESIDENT POPULATION***
Surficial contamination can generally be assumed.	Yes / No / Unk
	Is any residence, school, or daycare facility on or within 200 feet of an area of suspected contamination?
	Is any residence, school, or daycare facility located on adjacent land previously owned or leased by the site owner/operator?
	Is there a migration route that might spread hazardous substances near residences, schools, or daycare facilities?
	Have onsite or adjacent residents or students reported adverse health effects, exclusive of apparent drinking water or air contamination problems?
	Does any neighboring property warrant sampling?
	Other criteria?____________________
	RESIDENT POPULATION IDENTIFIED?

Summarize the rationale for Resident Population (attach an additional page if necessary):

SOIL EXPOSURE PATHWAY SCORESHEET

Pathway Characteristics

Answer the questions at the top of the page. Identify people who may be exposed to a hazardous substance because they work at the facility, or reside or attend school or daycare on or within 200 feet of an area of suspected contamination. If the site is active, estimate the number of full and part-time workers. Note that evaluation of targets is based on current site conditions.

Likelihood of Exposure (LE)

1. **Suspected Contamination:** Areas of surficial contamination are present at most sites, and a score of 550 can generally be assigned as a default measure. Assign zero, which effectively eliminates the pathway from further consideration, only if there is no surficial contamination; reliable analytical data are generally necessary to make this determination.

Resident Population Threat Targets (T)

2. **Resident Population** corresponds to "primary targets" for the migration pathways. Use professional judgment guided by the Soil Exposure Pathway Criteria List (page 18) to determine if there are people living or attending school or daycare on or within 200 feet of areas of suspected contamination. Record the number of people identified as resident population and multiply by 10 to determine the Resident Population factor score.

3. **Resident Individual:** Assign 50 if you have identified a resident population; otherwise, assign zero.

4. **Workers:** Estimate the number of full and part-time workers at this facility and adjacent facilities where contamination is also suspected. Assign a score for the Workers factor from the table.

5. **Terrestrial Sensitive Environments:** In the table provided, list each terrestrial sensitive environment located on an area of suspected contamination. Use PA Table 7 (page 20) to assign a value for each. Sum the values and assign the total as the factor score.

6. **Resources:** A score of 5 can generally be assigned as a default measure. Assign zero only if there is no land resource use on an area of suspected contamination.

Sum the target scores.

Waste Characteristics (WC)

7. Enter the WC score determined on page 4.

Resident Population Threat Score: Multiply the scores for LE, T, and WC. Divide the product by 82,500. Round the result to the nearest integer. If the result is greater than 100, assign 100.

Nearby Population Threat Score: Do not evaluate this threat if you gave a zero score to Likelihood of Exposure. Otherwise, assign a score based on the population within a 1-mile radius (use the same 1-mile radius population you evaluate for air pathway population targets):

Population Within One Mile	Nearby Population Threat Score
< 10,000	1
10,000 to 50,000	2
>50,000	4

Soil Exposure Pathway Score: Sum the Resident Population Threat score and the Nearby Population Threat score, subject to a maximum of 100.

SOIL EXPOSURE PATHWAY SCORESHEET

Pathway Characteristics		
Do any people live on or within 200 ft of areas of suspected contamination?	Yes ___	No ___
Do any people attend school or daycare on or within 200 ft of areas of suspected contamination?	Yes ___	No ___
Is the facility active? Yes ___ No ___ If yes, estimate the number of workers: ______		

	Suspected Contamination	*References*
LIKELIHOOD OF EXPOSURE		
1. SUSPECTED CONTAMINATION: Surficial contamination can generally be assumed, and a score of 550 assigned. Assign zero only if the absence of surficial contamination can be confidently demonstrated. **LE =**	(550 or 0) 550	______
RESIDENT POPULATION THREAT TARGETS		
2. RESIDENT POPULATION: Determine the number of people occupying residences or attending school or daycare on or within 200 feet of areas of suspected contamination (see Soil Exposure Pathway Criteria List, page 18). ______ people x 10 =	0	______
3. RESIDENT INDIVIDUAL: If you have identified a resident population (factor 2), assign a score of 50; otherwise, assign a score of 0.	(50 or 0) 0	______
4. WORKERS: Use the following table to assign a score based on the total number of workers at the facility and nearby facilities with suspected contamination:	(15, 10, 5, or 0) 5	______
5. TERRESTRIAL SENSITIVE ENVIRONMENTS: Use PA Table 7 to assign a value for each terrestrial sensitive environment on an area of suspected contamination: *Sum =*	25	______
6. RESOURCES	(5 or 0) 5	______
T =	35	
WASTE CHARACTERISTICS		
7. Assign the waste characteristics score calculated on page 4. **WC =**	(100, 32, or 18) 18/32	

Workers table (item 4):

Number of Workers	*Score*
0	0
1 to 100	5
101 to 1,000	10
> 1,000	15

Terrestrial sensitive environments table (item 5):

Terrestrial Sensitive Environment Type	*Value*
Wetlands	25

RESIDENT POPULATION THREAT SCORE: $\frac{LE \times T \times WC}{82{,}500}$ — (subject to a maximum of 100) 4.2/7.5

NEARBY POPULATION THREAT SCORE: (4, 2, or 0) 2 ______

SOIL EXPOSURE PATHWAY SCORE:
Resident Population Threat + Nearby Population Threat — (subject to a maximum of 100) 6.2/9.5

PA TABLE 7: SOIL EXPOSURE PATHWAY
TERRESTRIAL SENSITIVE ENVIRONMENT VALUES

Terrestrial Sensitive Environment	*Assigned Value*
Terrestrial critical habitat for Federally designated endangered or threatened species National Park Designated Federal Wilderness Area National Monument	100
Terrestrial habitat known to be used by Federally designated or proposed threatened or endangered species National Preserve (terrestrial) National or State terrestrial Wildlife Refuge Federal land designated for protection of natural ecosystems Administratively proposed Federal Wilderness Area Terrestrial areas utilized by large or dense aggregations of animals (vertebrate species) for breeding	75
Terrestrial habitat used by State designated endangered or threatened species Terrestrial habitat used by species under review for Federal designated endangered or threatened status	50
State lands designated for wildlife or game management State designated Natural Areas Particular areas, relatively small in size, important to maintenance of unique biotic communities	25

AIR PATHWAY CRITERIA LIST

This "Criteria List" helps guide the process of developing a hypothesis as to whether a release to the air is likely to be detected. The check-boxes record your professional judgment. Answers to all of the listed questions may not be available during the PA. Also, the list is not all-inclusive; if other criteria help shape your hypothesis, list them at the bottom of the page or attach an additional page.

The "Suspected Release" section identifies several conditions that could provide insight as to whether a release from the site is likely to be detected. If a release is suspected, primary targets are any residents, workers, students, and sensitive environments on or within ¼ mile of the site.

Check the boxes to indicate a "yes," "no," or "unknown" answer to each question. If you check the "Suspected Release" box as "yes," make sure you assign a Likelihood of Release value of 550 for the pathway.

AIR PATHWAY CRITERIA LIST	
SUSPECTED RELEASE	*PRIMARY TARGETS*
Y N U e o n s k ☐ ☐ ☐ Are odors currently reported? ☐ ☐ ☐ Has release of a hazardous substance to the air been directly observed? ☐ ☐ ☐ Are there reports of adverse health effects (e.g., headaches, nausea, dizziness) potentially resulting from migration of hazardous substances through the air? ☐ ☐ ☐ Does analytical or circumstantial evidence suggest a release to the air? ☐ ☐ Other criteria? ____________ ☐ ☐ **SUSPECTED RELEASE?**	If you suspect a release to air, evaluate all populations and sensitive environments within 1/4 mile (including those onsite) as primary targets.
Summarize the rationale for Suspected Release (attach an additional page if necessary):	

AIR PATHWAY SCORESHEET

Pathway Characteristics
Answer the questions at the top of the page. Refer to the Air Pathway Criteria List (page 21) to hypothesize whether you suspect that a hazardous substance release to the air could be detected. Due to dispersion, releases to air are not as persistent as releases to water migration pathways and are much more difficult to detect. Develop your hypothesis concerning the release of hazardous substances to air based on "real time" considerations. Record the distance (in feet) from any source to the nearest regularly occupied building.

Likelihood of Release (LR)

1. Suspected Release: Hypothesize based on professional judgment guided by the Air Pathway Criteria List (page 21). If you suspect a release to air, use only Column A for this pathway and do not evaluate factor 2.

2. No Suspected Release: If you do not suspect a release, enter 500 and use only Column B for this pathway.

Targets (T)

3. Primary Target Population: Evaluate populations subject to exposure from release of a hazardous substance from the site. If you suspect a release, the resident, student, and worker populations on and within ¼ mile of the site are considered primary target population. If only the number of residences is known, use the average county residents per household (rounded up to the next integer) to determine the population. In the space provided, enter this population. Multiply the population by 10 to determine the Primary Target Population score. Note that if you do not suspect a release, there can be no primary target population.

4. Secondary Target Population: Evaluate populations in distance categories not suspected to be subject to exposure from release of a hazardous substance from the site. If you suspect a release, residents, students, and workers in the ¼- to 4-mile distance categories are secondary target population. If you do not suspect a release, all residents, students, and workers onsite and within 4 miles are considered secondary target population.

Use PA Table 8 (page 23). Enter the population in each secondary target population distance category, circle the assigned value, and record it on the far-right side of the table. Sum the far-right column and enter the total as the Secondary Target Population factor score.

5. Nearest Individual represents the threat posed to the person most likely to be exposed to a hazardous substance release from the site. If you have identified a primary target population, enter 50. Otherwise, assign the score from PA Table 8 (page 23) for the closest distance category in which you have identified a secondary target population.

6. Primary Sensitive Environments: If a release is suspected, all sensitive environments on or within ¼ mile of the site are considered primary targets. List them and assign values for sensitive environment type (from PA Table 5, page 16) and/or wetland acreage (from PA Table 9, page 23). Sum the values and enter the total as the factor score.

7. Secondary Sensitive Environments: If a release is suspected, sensitive environments in the ¼- to ½-mile distance category are secondary targets; greater distances need not be evaluated because distance weighting greatly diminishes the impact on site score. If you do not suspect a release, all sensitive environments on and within ½ mile of the site are considered secondary targets. List each secondary sensitive environment on PA Table 10 (page 23) and assign a value to each using PA Tables 5 and 9. Multiply each value by the indicated distance weight and record the product in the far-right column. Sum the products and enter the total as the factor score.

8. Resources: A score of 5 can generally be assigned as a default measure. Assign zero only if there is no land resource use within ½ mile.

Sum the target scores in Column A (Suspected Release) or Column B (No Suspected Release).

Waste Characteristics (WC)

9. Waste Characteristics: Score is assigned from page 4. However, if you have identified any primary target for the air pathway, assign either the score calculated on page 4 or a score of 32, whichever is greater.

Air Pathway Score: Multiply the scores for LR, T, and WC. Divide the product by 82,500. Round the result to the nearest integer. If the result is greater than 100, assign 100.

AIR PATHWAY SCORESHEET

Pathway Characteristics		
Do you suspect a release (see Air Pathway Criteria List, page 21)?	Yes ___	No ___
Distance to the nearest individual:	______ ft	

	A Suspected Release	B No Suspected Release	References
LIKELIHOOD OF RELEASE			
1. SUSPECTED RELEASE: If you suspect a release to air (see page 21), assign a score of 550. Use only column A for this pathway.	550		
2. NO SUSPECTED RELEASE: If you do not suspect a release to air, assign a score of 500. Use only column B for this pathway.		500 500	
LR =		500	
TARGETS			
3. PRIMARY TARGET POPULATION: Determine the number of people subject to exposure from a suspected release of hazardous substances to the air. ______ people x 10 =			
4. SECONDARY TARGET POPULATION: Determine the number of people not suspected to be exposed to a release to air, and assign the total population score using PA Table 8.		11	
5. NEAREST INDIVIDUAL: If you have identified any Primary Target Population for the air pathway, assign a score of 50; otherwise, assign the Nearest Individual score from PA Table 8.	50, 20, 7, 2, 1, or 0	20, 7, 2, 1, or 0 20	
6. PRIMARY SENSITIVE ENVIRONMENTS: Sum the sensitive environment values (PA Table 5) and wetland acreage values (PA Table 9) for environments subject to exposure from a suspected release to the air. Sum =			
7. SECONDARY SENSITIVE ENVIRONMENTS: Use PA Table 10 to determine the score for secondary sensitive environments.		0	
8. RESOURCES	5 or 0	5 or 0 5	
T =		36	
WASTE CHARACTERISTICS			
9. A. If you have identified any Primary Target for the air pathway, assign the waste characteristics score calculated on page 4, or a score of 32, whichever is GREATER; do not evaluate part B of this factor.	100 or 32		
B. If you have NOT identified any Primary Target for the air pathway, assign the waste characteristics score calculated on page 4.	100, 32, or 18	100, 32, or 18 18/32	
WC =			

Sensitive Environment Type	Value

AIR PATHWAY SCORE: $\frac{LR \times T \times WC}{82,500}$ = 3.9 / 7.0 (subject to a maximum of 100)

PA TABLE 8: VALUES FOR SECONDARY AIR TARGET POPULATIONS

Distance from Site	*Population*	*Nearest Individual (choose highest)*	*Population Within Distance Category* *1 to 10*	*11 to 30*	*31 to 100*	*101 to 300*	*301 to 1,000*	*1,001 to 3,000*	*3,001 to 10,000*	*10,001 to 30,000*	*30,001 to 100,000*	*100,001 to 300,000*	*300,001 to 1,000,000*	*Greater than 1,000,000*	*Population Value*
Onsite	≤ 10	20	1	2	5	16	52	163	521	1,633	5,214	16,325	52,136	163,246	1
>0 to ¼ mile	≤ 10	20	1	1	1	4	13	41	130	408	1,303	4,081	13,034	40,811	1
> ¼ to ½ mile	1,000	2	0	0	1	1	3	9	28	88	282	882	2,815	8,815	3
> ½ to 1 mile	2,000	1	0	0	0	1	1	3	8	26	83	261	834	2,612	3
> 1 to 2 miles	3,000	0	0	0	0	0	1	1	3	8	27	83	266	833	1
> 2 to 3 miles	2,000	0	0	0	0	0	1	1	1	4	12	38	120	376	1
> 3 to 4 miles	2,000	0	0	0	0	0	0	1	1	2	7	23	73	229	1

Nearest Individual = 20

Score = 11

PA TABLE 9: AIR PATHWAY VALUES FOR WETLAND AREA

Wetland Area	*Assigned Value*
Less than 1 acre	0
1 to 50 acres	25
Greater than 50 to 100 acres	75
Greater than 100 to 150 acres	125
Greater than 150 to 200 acres	175
Greater than 200 to 300 acres	250
Greater than 300 to 400 acres	350
Greater than 400 to 500 acres	450
Greater than 500 acres	500

PA TABLE 10: DISTANCE WEIGHTS AND CALCULATIONS FOR AIR PATHWAY SECONDARY SENSITIVE ENVIRONMENTS

Distance	*Distance Weight*	*Sensitive Environment Type and Value (from PA Table 5 or 9)*	*Product*
Onsite	0.10	x	
		x	
0-1/4 mi	0.025	x	
		x	
		x	
1/4-1/2mi	0.0054	x	
		x	
		x	
		x	

Total Environments Score =

SITE SCORE CALCULATION

In the column labeled S, record the Ground Water Pathway score, the Surface Water Pathway score, the Soil Exposure Pathway score, and the Air Pathway score. Square each pathway score and record the result in the S^2 column. Sum the squared pathway scores. Divide the sum by 4, and take the square root of the result to obtain the **Site Score**.

SUMMARY

Answer the summary questions, which ask for a qualitative evaluation of the relative risk of targets being exposed to a hazardous substance from the site. You may find your responses to these questions a good cross-check against the way you scored the individual pathways. For example, if you scored the ground water pathway on the basis of no suspected release and secondary targets only, yet your response to question #1 is "yes," this presents apparently conflicting conclusions that you need to reconsider and resolve. Your answers to the questions on page 24 should be consistent with your evaluations elsewhere in the PA scoresheets package.

WC = 18

SITE SCORE CALCULATION

	S	S^2
GROUND WATER PATHWAY SCORE (S_{gw}):	12.8	163.8
SURFACE WATER PATHWAY SCORE (S_{sw}):	4.7	22.1
SOIL EXPOSURE PATHWAY SCORE (S_s):	6.2	38.4
AIR PATHWAY SCORE (S_a):	3.9	15.2
SITE SCORE:	$\sqrt{\frac{S_{gw}^2+S_{sw}^2+S_s^2+S_a^2}{4}}$	$\sqrt{60.0} = 7.7$

SUMMARY

	YES	NO
1. Is there a high possibility of a threat to any nearby drinking water well(s) by migration of a hazardous substance in ground water?	☐	☐
A. If yes, identify the well(s). ______		
B. If yes, how many people are served by the threatened well(s)? ______		
2. Is there a high possibility of a threat to any of the following by hazardous substance migration in surface water?		
A. Drinking water intake	☐	☐
B. Fishery	☐	☐
C. Sensitive environment (wetland, critical habitat, others)	☐	☐
D. If yes, identify the target(s). ______		
3. Is there a high possibility of an area of surficial contamination within 200 feet of any residence, school, or daycare facility? If yes, identify the property(ies) and estimate the associated population(s). ______	☐	☐
4. Are there public health concerns at this site that are not addressed by PA scoring considerations? If yes, explain: ______	☐	☐

WC = 32

SITE SCORE CALCULATION

	S	S^2
GROUND WATER PATHWAY SCORE (S_{gw}):	22.8	519.8
SURFACE WATER PATHWAY SCORE (S_{sw}):	8.6	73.96
SOIL EXPOSURE PATHWAY SCORE (S_s):	9.5	90.3
AIR PATHWAY SCORE (S_a):	7.0	49
SITE SCORE: $\sqrt{\frac{S_{gw^2}+S_{sw^2}+S_{s^2}+S_{a^2}}{4}}$		$\sqrt{183.3}$ = 13.5

SUMMARY

	YES	NO
1. Is there a high possibility of a threat to any nearby drinking water well(s) by migration of a hazardous substance in ground water?	☐	☐
A. If yes, identify the well(s). ______		
B. If yes, how many people are served by the threatened well(s)? ______		
2. Is there a high possibility of a threat to any of the following by hazardous substance migration in surface water?		
A. Drinking water intake	☐	☐
B. Fishery	☐	☐
C. Sensitive environment (wetland, critical habitat, others)	☐	☐
D. If yes, identify the target(s). ______		
3. Is there a high possibility of an area of surficial contamination within 200 feet of any residence, school, or daycare facility?	☐	☐
If yes, identify the property(ies) and estimate the associated population(s). ______		
4. Are there public health concerns at this site that are not addressed by PA scoring considerations? If yes, explain: ______	☐	☐

REFERENCE 1

GA

DEFENSE ENVIRONMENTAL RESTORATION PROGRAM
FOR FORMERLY USED SITES
INVENTORY PROJECT REPORT
WAYCROSS ARMY AIRFIELD
WAYCROSS, WARE COUNTY, GEORGIA
PROJECT NO. I04GA059200

TABLE OF CONTENTS

PART I - PROJECT DESCRIPTION

PROJECT DESCRIPTION
WAYCROSS ARMY AIRFIELD
WAYCROSS, WARE COUNTY, GEORGIA
PROJECT NO. I04GA059200

1. INTRODUCTION

At the request of the South Atlantic Division, the Savannah District initiated a study and inventory of possible hazardous waste at the former Waycross Army Airfield site, a former Department of Defense (DOD) property, in June 1987.

2. PROJECT DESCRIPTION

A low-level hazardous and toxic waste removal project is proposed to locate, pump out, fill with inert material, and seal an underground storage tank. The tank is a potential source of low-level contaminants.

3. DESCRIPTION OF SITE

a. The former Waycross Army Airfield is currently known as the Waycross/Ware County Airport. It is located in Ware County, northwest of Waycross, between U.S. Highways No. 1 and No. 82. The airport is adjacent to an industrial park and also located next to the county prison. All these facilities are on property which was once owned by the DOD. The public has unrestricted access to the airport, however, the location of the fueling station, which appears to have an underground tank, has limited access. No discoloration of the soil or ground disturbance was observed at this refueling station.

b. The project site is a property acquired for the War Department for use as a main base for combat crew training. A Prisoner of War camp was also located on the property. The area consists of an airfield with several runways and associated buildings and hangers. Many of these buildings are left from DOD ownership; however, all are being or have been put to beneficial uses since the property was declared excess. The Prisoner of War camp has been expanded and modified as the Ware County Prison. Other DOD property which comprised the former Waycross Army Airfield is being used as an industrial park and contains a lumber yard, Scott Housing Systems, Inc., Sue Bee Honey, and other businesses. Former DOD buildings and facilities in this industrial park have been demolished or modified and the area bears little resemblance to the former airfield and training facility. Some areas on the current airport property are planted with soybeans, watermelons, and other crops. Other areas are in timber production.

Attachment 1 - Site Survey Summary Sheet

SITE SURVEY SUMMARY SHEET
FOR
PROJECT NO. I04GA059200

SITE NAME: Waycross Army Airfield.

LOCATION: Waycross, Ware County, Georgia.

DESCRIPTION OF PROBLEM: Underground fuel storage tank possibly containing petroleum products or residues associated with an airplane fueling station.

SITE HISTORY: The property was acquired partially in fee and partially in lease during the period 1943-1946 by the War Department for use as a Prisoner of War camp and for combat training. The site was declared excess in 1945 and transferred by quitclaim deed to Ware County and the City of Waycross in 1947.

AVAILABLE STUDIES AND REPORTS: Savannah District has the acquisition and disposal records.

CATEGORY OF HAZARD: Potential low-level hazardous/toxic contamination.

BASIS FOR DETERMINATION OF DOD RESPONSIBILITY: Potentially hazardous structures were installed and used by DOD and have not been used by subsequent owners.

POC/DISTRICT: Stanley Rikard, Commercial (912) 944-5816/Savannah District.

STATUS: The site is currently owned and operated by the City of Waycross and Ware County.

DESCRIPTION OF PROPOSED REMEDIAL ACTION: A two phase plan of work is proposed. Phase 1 calls for an investigation to locate the fuel tank, estimate the size and condition, and obtain bottom and vapor samples. The results from this phase will determine what actions, if any, are needed in Phase 2. Assuming "worst case" and condition (i.e., a fuel tank half full), the tank contents would be pumped into drums for proper disposal and the tank itself decontaminated. The tank would then be exposed, punctured, and backfilled to the surrounding grade.

ESTIMATED COST: $12,700.

Attachment 2 - Cost Estimate

1. COMPONENT	FY 19 87 MILITARY CONSTRUCTION PROJECT DATA	2. DATE
ARMY		4 Sep 87

3. INSTALLATION AND LOCATION	4. PROJECT TITLE
Waycross Army Airfield Waycross, Ware County, Georgia	Defense Environmental Restoration Program

5. PROGRAM ELEMENT	6. CATEGORY CODE	7. PROJECT NUMBER	8. PROJECT COST ($000)
		I04GA059200	12.7

9. COST ESTIMATES

ITEM	U/M	QUANTITY	UNIT COST	COST ($000)
Construction Cost (Phase 2)				9.0
Pump tank, loads contents into drum, & decontaminate tank	LS			(5.0)
Disposal of tank contents	EA	10	0.2	(2.0)
Expose and puncture tank, backfill tank, & cover to grade	LS			(2.0)
Contingencies (10%)				0.9
Supervision & Administration (7.5%)				0.7
TOTAL CONSTRUCTION CWE				10.6
Phase 1 Investigation	LS			1.5
Design (6%)				0.6
TOTAL IMPLEMENTATION COST				12.7

10. DESCRIPTION OF PROPOSED CONSTRUCTION

A two phase plan of work is proposed. Phase 1 calls for an additional on-site investigation to locate the fuel tank, estimate the size and condition, and obtain bottom and vapor samples. The results from this phase will determine what actions, if any, are needed in Phase 2. Assuming "worst case" condition (i.e., a fuel tank half full), the tank contents would be pumped into drums for proper disposal and the tank itself decontaminated. The tank would then be exposed, punctured, and backfilled to the surrounding grade.

Attachment 3 - Site Photographs

INVENTORY PROJECT REPORT
ATTACHMENT NO. 3
PROJECT NUMBER I04GA059200
WAYCROSS ARMY AIR FIELD - WAYCROSS, GEORGIA

ONE OF TWO FUELING ISLANDS AT CORNER OF FOREST ROAD AND KEEN ROAD. MAGNETOMETER INDICATED NO UNDERGROUND TANKS HERE.

ONE OF TWO FUELING ISLANDS AT CORNER OF FOREST ROAD AND KEEN ROAD. MAGNETOMETER INDICATED NO UNDERGROUND TANKS HERE.

INVENTORY PROJECT REPORT
ATTACHMENT NO. 3
PROJECT NUMBER I04GA059200
WAYCROSS ARMY AIR FIELD - WAYCROSS, GEORGIA

ONE OF TWO FUELING ISLANDS WHERE
MAGNETOMETER READINGS INDICATE A SMALL
UNDERGROUND TANK.

PART II - FINDINGS AND DETERMINATION OF ELIGIBILITY

DEFENSE ENVIRONMENTAL RESTORATION PROGRAM
FOR FORMERLY USED SITES
FINDINGS AND DETERMINATION OF ELIGIBILITY
WAYCROSS ARMY AIRFIELD
WAYCROSS, WARE COUNTY, GEORGIA
PROJECT NO. I04GA059200

FINDINGS OF FACT

1. A low-level hazardous and toxic waste removal project is proposed at the former Waycross Army Airfield, located in Ware County approximately 2 miles northwest of Waycross, Georgia. The project consists of locating an underground storage tank suspected to be located at an airport fueling station. The tank will be pumped out, filled with inert material, and sealed. The tank is a potential source of environmental contamination.

2. The Waycross Army Airfield installation consisted of 36.25 acres fee acquired by purchase, 2,533.35 acres acquired by lease, and avigation easements over 64.34 acres acquired from 1943-1946.

3. Waycross Army Airfield was used by the Army as a main base for combat crew training. Extensive improvements were made during the period the base was operational. It is difficult to determine what improvements, if any, were in existence prior to Government ownership and control. The area remained under Department of Defense (DOD) control during the period of DOD ownership and use.

4. Waycross Army Airfield was declared surplus to Army needs and on 9 November 1946, was transferred to the War Assets Administration (WAA) for disposal. By quitclaim deed dated 1 July 1947, WAA conveyed avigation easements over 64.34 acres, 36.25 acres fee, and 2,521.90 acres of leased lands with improvements to Ware County and the City of Waycross. The deed restricted use to airport purposes and contained a recapture clause. The deed stated that grantee would maintain the land and improvements for the use and benefit of the public. There was no restoration provision. Leases on 11.45 acres were allowed to expire 6 months after the end of WWII.

5. The underground tank has not been used since DOD disposal of the site. The current owner has requested its removal. There is no other evidence of unsafe debris, hazardous or toxic waste, or unexploded ordnance resulting from DOD use of the site.

PROJECT NO. I04GA059200

DETERMINATION

Based on the foregoing findings of fact, the site has been determined to have been formerly used by DOD. Moreover, it is determined that an environmental restoration project, to the extent set out herein, is an appropriate undertaking within the purview of the Defense Environmental Restoration Program, established under 10 U.S.C. 2701 et seq., for the reasons stated above.

26 June 87
DATE

LLOYD A. DUSCHA, P.E.
Deputy Director
Directorate of Military Programs

PART III - POLICY CONSIDERATIONS

POLICY CONSIDERATIONS
WAYCROSS ARMY AIRFIELD
WAYCROSS, WARE COUNTY, GEORGIA
PROJECT NO. I04GA059200

Current DOD policy permits remediation of DOD generated hazardous and toxic waste regardless of the current status of the site. With respect to the former Waycross Army Airfield, the tank was generated by DOD and has not been benficially used by the current owner.

PART IV - PROJECT RECOMMENDATIONS

PROJECT RECOMMENDATIONS
WAYCROSS ARMY AIRFIELD
WAYCROSS, WARE COUNTY, GEORGIA
PROJECT NO. I04GA059200

1. It is recommended that the project be approved as proposed. A low implementation priority is recommended, based on the low potential for direct exposure of people in the area.

Ref - B

REFERENCE 2

National Water Summary 1984

Hydrologic Events, Selected Water-Quality Trends, and Ground-Water Resources

By United States Geological Survey

United States Geological Survey Water-Supply Paper 2275

DEPARTMENT OF THE INTERIOR
DONALD PAUL HODEL, Secretary

U.S. GEOLOGICAL SURVEY
Dallas L. Peck, Director

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GEORGIA
Ground-Water Resources

Ground water is an abundant natural resource in Georgia and comprises 18 percent of the total freshwater used (including thermoelectric) in the State. Georgia's aquifers provide water for more than 2.6 million people, or almost one-half of the total population of the State. Of this number, about one-half are served by public water-supply systems and one-half by rural water-supply systems. Most ground-water withdrawals are in the southern one-half of the State where the aquifers are very productive. Ground-water withdrawals in 1980 for various uses, and related statistics, are given in table 1.

GENERAL SETTING

Differing geologic features and landforms of the several physiographic provinces of Georgia cause significant differences in ground-water conditions from one part of the State to another (fig. 1). The most productive aquifers in the State are located in the Coastal Plain province in the southern one-half of Georgia; the province is underlain by alternating layers of sand, clay, and limestone that dip and thicken to the southeast. Aquifers generally are confined in the Coastal Plain, except near their northern limit where the formations are exposed or are near land surface. Principal aquifers of the Coastal Plain include the Floridan aquifer system, the Claiborne aquifer, the Clayton aquifer, and the Cretaceous aquifer system (table 2). The Piedmont and Blue Ridge provinces, which include most of the northern one-half of Georgia, are underlain by massive igneous and metamorphic rocks that form aquifers of very low permeability. The Valley and Ridge and Appalachian Plateaus provinces, which are in the northwestern corner of Georgia, are underlain by layers of sandstone, limestone, dolostone, and shale of Paleozoic age.

Recharge to the ground-water system in Georgia is derived almost entirely from precipitation. Average annual precipitation based on the 30-year period of record (1941-70) is about 50 inches (in.) statewide and ranges from about 44 in. in the east-central part of the State to about 76 in. in the northeastern corner of the State. Of this amount, about 88 percent is discharged to streams or is lost to evapotranspiration, and about 12 percent enters the ground-water system as recharge (Carter and Stiles, 1983).

PRINCIPAL AQUIFERS

FLORIDAN AQUIFER SYSTEM

The Floridan aquifer system is one of the most productive ground-water reservoirs in the United States. More than 600 million gallons per day (Mgal/d) is withdrawn from the aquifer system in Georgia (1980), making it the principal source of ground water in the State. The aquifer system generally is confined but is semiconfined to unconfined near its northern limit and near areas of karst topography in the Dougherty Plain and near Valdosta. In parts of the area where the Floridan aquifer system is exposed or is near land surface, intensive pumping can contribute to the formation of sinkholes. Although water suitable for most uses can be obtained from the aquifer system throughout most of the Coastal Plain, water-quality problems have occurred in some areas. The following examples serve to illustrate the problem: (1) at Brunswick, the intrusion of brackish water into the aquifer system resulted in chloride concentrations of as much as 1,000 milligrams per liter (mg/L) in some wells (Wait and Gregg, 1973), (2) in the area of Wheeler and Montgomery Counties in central-south Georgia, naturally occurring radioactivity exceeds 25 picocuries per liter (S. S. McFadden, Georgia Geologic Survey, oral commun., September 1984), (3) in nearby Ben Hill County, barium concentrations of as much as 2.1 mg/L are present in some wells (S. S. McFadden, Georgia Geologic Survey, oral commun., September 1984), (4) at Valdosta, naturally occurring organic substances, color and hydrogen sulfide gas have been a cause of concern (Krause, 1979), and (5) in the Dougherty Plain area, small concentrations of commonly used pesticides have been detected in some farm wells (Hayes and others, 1983).

Table 1. Ground-water facts for Georgia

[Withdrawal data rounded to two significant figures and may not add to totals because of independent rounding. Mgal/d = million gallons per day; gal/d = gallons per day. Source: Solley, Chase, and Mann, 1983]

Population served by ground water, 1980	
Number (thousands)	2,604
Percentage of total population	48
From public water-supply systems:	
Number (thousands)	1,320
Percentage of total population	24
From rural self-supplied systems:	
Number (thousands)	1,284
Percentage of total population	23
Freshwater withdrawals, 1980	
Surface water and ground water, total (Mgal/d)	6,700
Ground water only (Mgal/d)	1,200
Percentage of total	18
Percentage of total excluding withdrawals for thermoelectric power	52
Category of use	
Public-supply withdrawals:	
Ground water (Mgal/d)	230
Percentage of total ground water	19
Percentage of total public supply	29
Per capita (gal/d)	174
Rural-supply withdrawals:	
Domestic:	
Ground water (Mgal/d)	140
Percentage of total ground water	12
Percentage of total rural domestic	100
Per capita (gal/d)	109
Livestock:	
Ground water (Mgal/d)	17
Percentage of total ground water	1
Percentage of total livestock	61
Industrial self-supplied withdrawals:	
Ground water (Mgal/d)	400
Percentage of total ground water	34
Percentage of total industrial self-supplied:	
Including withdrawals for thermoelectric power	8
Excluding withdrawals for thermoelectric power	57
Irrigation withdrawals:	
Ground water (Mgal/d)	380
Percentage of total ground water	32
Percentage of total irrigation	66

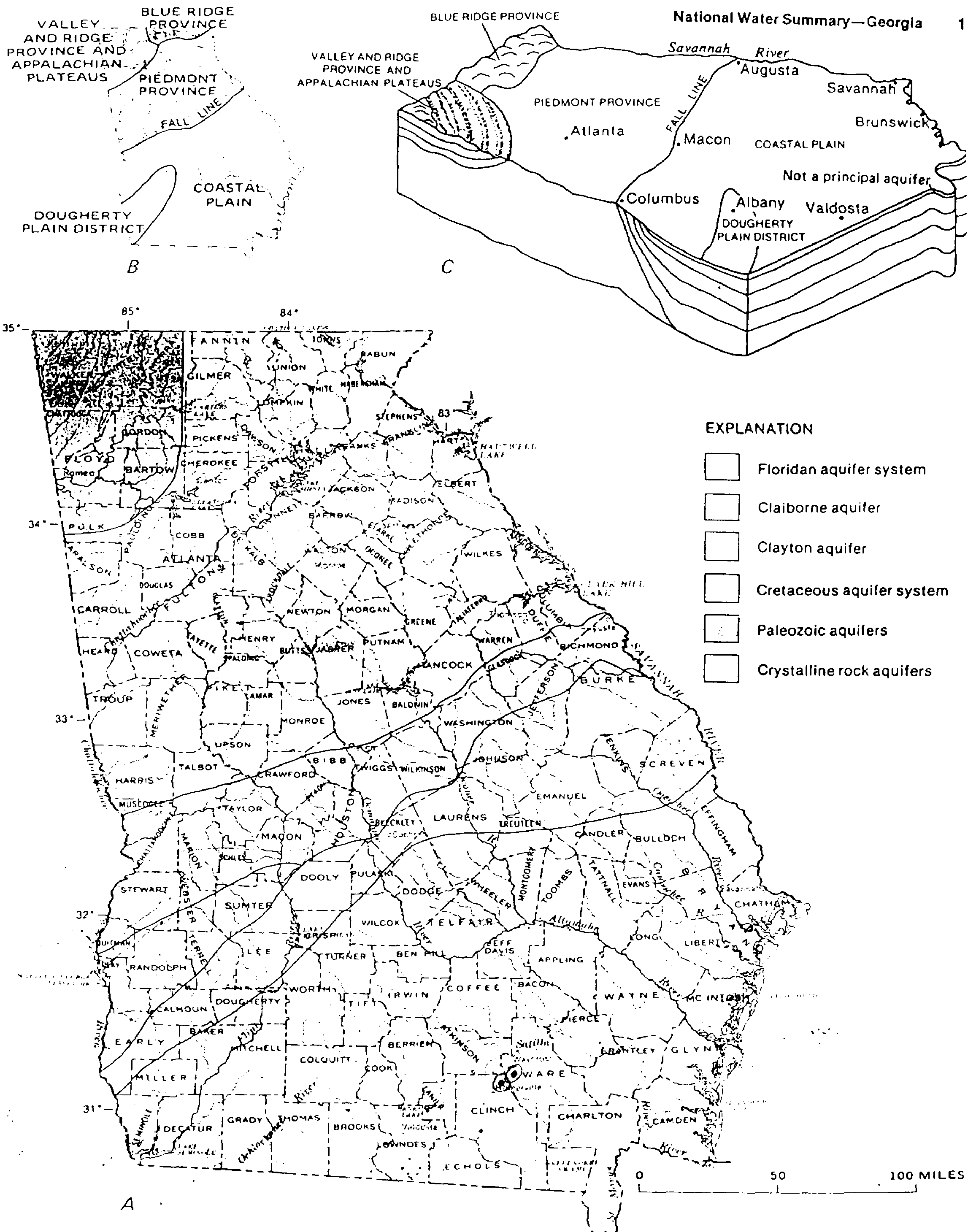
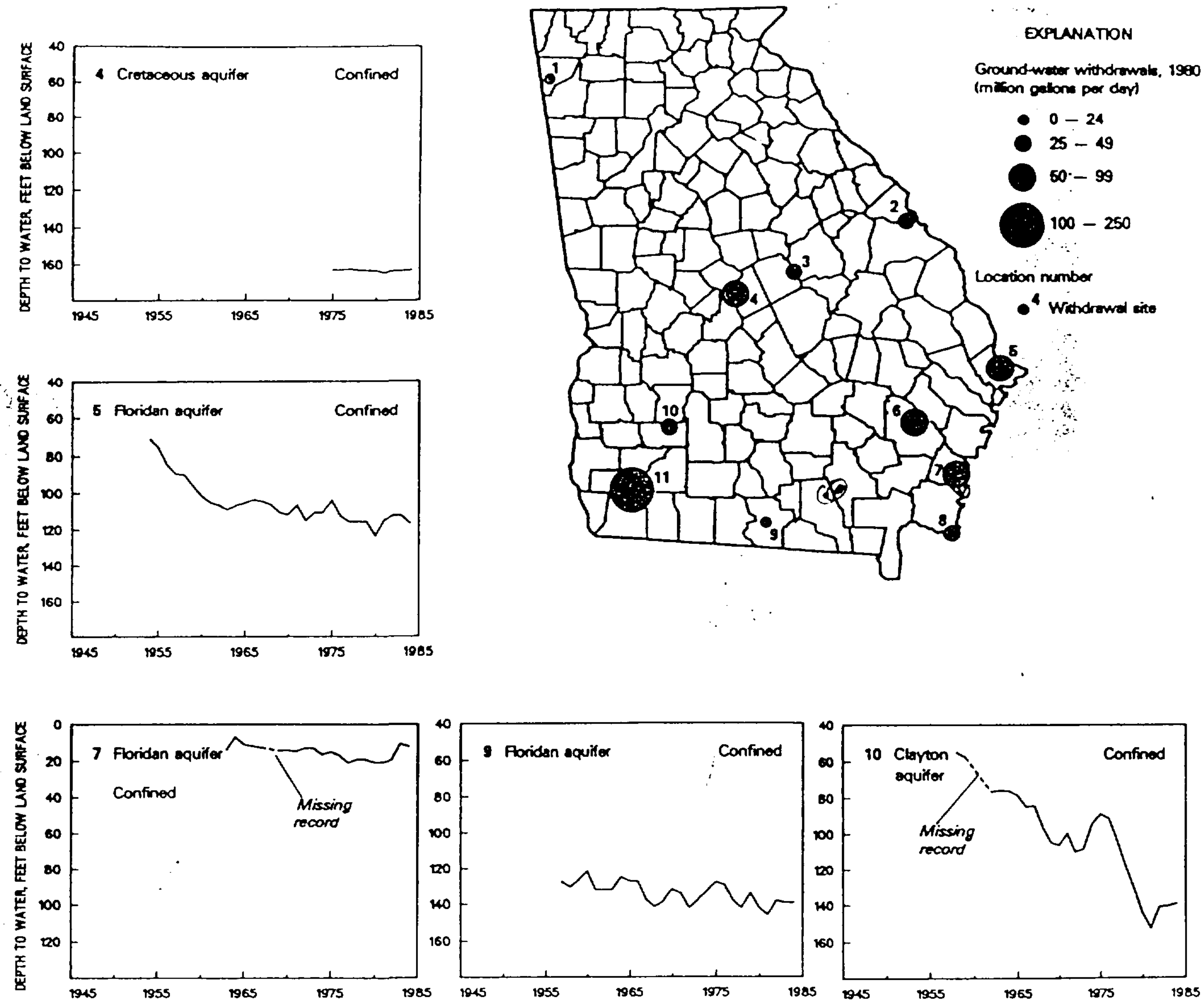


Figure 1. Principal aquifers in Georgia. *A*, Geographic distribution. *B*, Physiographic diagram and divisions. *C*, Block diagrai showing principal aquifers and physiographic divisions. (See table 2 for a more detailed description of the aquifers. Sources: / J. S. Clarke, U.S. Geological Survey, written commun., 1984. *B*, Fenneman, 1938; Raisz, 1954. *C*, Modified from Pierce an others, 1984.)

Table 2. Aquifer and well characteristics in Georgia

[Ft = feet; gal/min = gallons per minute. Sources: Reports of the U.S. Geological Survey and Georgia Geologic Survey]

Aquifer name and description	Well characteristics: Depth (ft) Common range	Yield (gal/min) Common range	Yield (gal/min) May exceed	Remarks
Floridan aquifer system: Limestone, dolomite, and calcareous sand. Generally confined.	40 - 900	1,000 - 5,000	11,000	Supplies 50 percent of ground water in State. Major users include the Savannah, the Brunswick, the Jesup, the St. Marys, the Albany, and the Dougherty Plain areas. Water-level declines at Savannah and Brunswick. Intrusion of brackish water from deeper zones at Brunswick. In some areas, water has natural radioactivity that exceeds State and national drinking-water regulations. Formerly called principal artesian aquifer.
Claiborne aquifer: Sand and sandy limestone. Generally confined.	20 - 450	150 - 600	1,500	Major source of water in southwestern Georgia. Supplies industrial and municipal users at Dougherty, Crisp and Dooly Counties and provides irrigation water north of Dougherty Plain. Called Tertiary sands aquifer in South Carolina and Tennessee. Part of Tertiary sedimentary aquifer system in Alabama.
Clayton aquifer: Limestone and sand. Generally confined.	40 - 800	250 - 600	2,150	Major source of water in southwestern Georgia. Supplies industrial and municipal users at Albany and provides irrigation water northwest of Albany. Water-level declines exceed 100 ft at Albany. Iron concentrations in Randolph County exceed national drinking-water regulations. Part of Tertiary sedimentary aquifer system in Alabama.
Cretaceous aquifer system: Sand and gravel. Generally confined.	30 - 750	50 - 1,200	3,300	Major source of water in east-central Georgia. Supplies water for kaolin mining and processing. Includes Providence aquifer in southwestern Georgia. Water-level declines greater than 50 ft at kaolin mining centers and 100 ft near Albany. Iron concentrations exceed national drinking-water regulations in some areas. Called Black Creek and Middendorf aquifers in South Carolina.
Paleozoic aquifers: Sandstone, limestone, and dolomite; storage is in regolith and fractures and solution openings in rock. Generally unconfined.	15 - 2,100	1 - 50	3,500	Not laterally extensive. Limestone and dolomite aquifers most productive. Springs in limestone and dolostone aquifers discharge at rates of as much as 5,000 gal/min. Sinkholes can form in areas of intensive pumping. Water is generally of good quality, although contamination from septic tanks and farm waste reported in some areas. Laterally equivalent to Paleozoic carbonate aquifers in Alabama and Pennsylvanian sandstone aquifers in Alabama and Tennessee.
Crystalline rock aquifers: Granite, gneiss, schist, and quartzite; storage is in fractures in rock and in regolith. Generally unconfined.	40 - 600	1 - 25	500	Not laterally extensive. Water of good quality with exception of large concentrations of iron and manganese in some areas and contamination from septic tank effluent in densely populated areas.



WITHDRAWAL SITES			
No. on map	Geographic area	Aquifer	Principal uses
1	Valley and Ridge . . .	Paleozoic.	Carpet mill industry.
2	Richmond-Burke . . .	Cretaceous	Public supply, industrial, irrigation.
3	Kaolin Belt.	. . . .do	Clay mining and processing.
4	Huber-Warner Robins.	. . . .do	Clay mining and processing, public supply.
5	Savannah.	Floridan	Public supply, chemical industry, pulp and paper industry.
6	Jesup	. . . .do	Pulp and paper industry.
7	Brunswick	. . . .do	Pulp and paper industry, public supply.
8	St. Marys.	. . . .do	Pulp and paper industry.
9	Valdosta	. . . .do	Public supply, industrial.
10	Albany.	Floridan, Clayton, Claiborne, Providence.	Public supply, industrial, irrigation.
11	Dougherty Plain. . . .	Floridan	Irrigation.

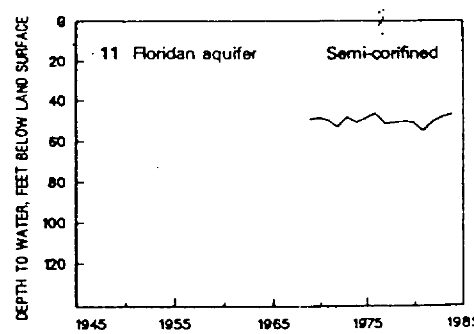


Figure 2. Areal distribution of major ground-water withdrawals and graphs of annual greatest depth to water in selected wells Georgia. (Sources: Withdrawal data from Pierce and others, 1982; water-level data from U.S. Geological Survey files.)

Claiborne Aquifer

The Claiborne aquifer is an important source of water in part of southwestern Georgia (fig. 1) and supplied an estimated 36 Mgal/d in 1980, primarily for irrigation (McFadden and Perriello, 1983). Although the Claiborne aquifer yields water suitable for most uses over most of its extent, naturally occurring concentrations of dissolved solids and chloride in the south-central part of the State have been reported as 22,200 and 11,900 mg/L, respectively (Wait, 1960).

Clayton Aquifer

The Clayton aquifer is an important source of water in southwestern Georgia (fig. 1), where it supplied an estimated 20 Mgal/d in 1980. Most of the withdrawals were for public supply (58 percent) and irrigation (35 percent). With the exception of large concentrations of iron (greater than 0.3 mg/L) in Randolph County, water from the aquifer is suitable for most uses (Clarke and others, 1984).

Cretaceous Aquifer System

The Cretaceous aquifer system is a major source of water in the northern one-third of the Coastal Plain (fig. 1). During 1980, the aquifer system yielded an estimated 128 Mgal/d, primarily for industrial and public-supply use. The aquifer system consists of sand and gravel that locally contain layers of clay and silt which function as confining beds. These confining beds locally separate the aquifer system into two or more aquifers. In southwestern Georgia, the Providence aquifer is part of the Cretaceous aquifer system. Water from the aquifer system is soft (less than 60 mg/L as calcium carbonate), has little dissolved solids (generally less than 100 mg/L), and is of a sodium bicarbonate type that is suitable for most uses. In the center of the area of usage (fig. 1), the iron concentration may be as much as 6.7 mg/L.

Paleozoic Aquifers

Water in the Paleozoic aquifers generally is unconfined, and storage is limited mainly to joints, fractures, and solution openings in the bedrock. During 1980, an estimated 33 Mgal/d was withdrawn from the Paleozoic aquifers, primarily for industrial supply. Wells that tap the Paleozoic aquifers yield differing amounts of water, depending on the aquifer used. Dolostone aquifers typically yield 5 to 50 gallons per minute (gal/min), whereas limestone and sandstone aquifers typically yield 1 to 20 gal/min; maximum reported yields from these aquifers are 3,500 and 300 gal/min, respectively. Springs discharge from the limestone and dolostone aquifers at rates of as much as 5,000 gal/min. Where the limestone and dolostone aquifers are near land surface, pumping can contribute to the formation of sinkholes. Water from wells and springs in the Paleozoic aquifers generally is suitable for most uses, although contamination from septic tanks and farm waste has been reported (Cressler and others, 1976).

Crystalline Rock Aquifers

Although individual crystalline rock aquifers are not laterally extensive, collectively they yielded an estimated 99 Mgal/d in 1980, primarily for rural supply. Ground-water storage occurs in the regolith and where the rocks have joints, fractures, and other types of secondary openings (Cressler and others, 1983). Crystalline rock aquifers in these areas generally are unconfined and show a pronounced response to rainfall, although deep fracture systems commonly are confined. Water from the aquifers generally is suitable for most uses, and, with the exception of iron (as much as 14 mg/L) and manganese (as much as 1.5 mg/L), constituent concentrations rarely exceed national drinking-water regulations (U.S. Environmental Protection Agency, 1982a,b). In some densely populated areas, septic-tank effluent has contaminated the aquifers (Cressler and others, 1983).

GROUND-WATER WITHDRAWALS AND WATER-LEVEL TRENDS

Major areas of ground-water withdrawals and trends in ground-water levels near selected pumping centers are shown in figure 2. With the exception of one center in the Valley and Ridge province (location 1, fig. 2), all major pumping centers are in the Coastal Plain, where aquifers are very productive. The largest pumping center is the Dougherty Plain area where ground-water withdrawal for irrigation exceeds 200 Mgal/d.

The hydrographs shown in figure 2 reflect the responses of aquifers to pumping at selected pumping centers under a variety of hydrologic conditions. In the Floridan aquifer system, large cones of depression have formed at Savannah, Brunswick, Jesup, and St. Marys as a result of pumping for industrial and public supply. At Savannah (location 5, fig 2.), the water level has declined at least 160 feet (ft) since pumping began in the late 1800's (McCollum and Counts, 1964). The hydrograph shows that the water level declined 45 ft from 1954 to 1961 and less than 10 ft from 1961 to 1984. These changes reflect pumping patterns in the area. At Brunswick, the water level in the aquifer system declined 65 ft from predevelopment to 1964 (Wait and Gregg, 1973). The decline continued until 1982 (location 7, fig. 2), then rose about 10 ft as the result of a significant decrease in pumping by a major water user. Near Valdosta (location 9, fig. 2), the water level in the Floridan aquifer system responds to changes in recharge derived from streamflow and to local pumping. The hydrograph shows a moderate long-term response to changing recharge rates and to pumping. Pumpage from the Floridan aquifer system in the Dougherty Plain area (location 11, fig. 2) is primarily for seasonal irrigation which, averaged over the year, exceeded 200 Mgal/d in 1980. In this area, pumpage is scattered widely. Some recharge to the Floridan aquifer system occurs locally. As a result, water-levels recover annually.

In the Albany area (location 10, fig. 2), water is withdrawn from the Tertiary Floridan aquifer system, the Claiborne aquifer, and the Clayton aquifer and the Cretaceous Providence aquifer. Water-level declines of more than 100 ft have occurred in the Clayton and Providence aquifers (Clarke and others, 1983, 1984). The water level in the Clayton aquifer near withdrawal location 10 (fig. 2) generally declined from 1958 to 1984 in response to increased pumping for public supply and agriculture.

The water level in the Cretaceous aquifer system has declined more than 50 ft since 1950 in areas of heavy pumping for public supply and industrial use. However, in the Huber-Warner Robins area (location 4, fig. 2), the water level has not declined significantly from 1975 to 1984 despite a slight increase in ground-water withdrawals during that period.

GROUND-WATER MANAGEMENT

Georgia has a comprehensive set of laws governing the quality and use of ground water. The Ground-Water Use Act of 1972 provided for the permitting of withdrawals for industrial and municipal use that exceed 100,000 gallons per day (gal/d) and authorized the Georgia Environmental Protection Division to issue regulations about reporting, timing of withdrawals, abatement of saltwater encroachment, well depth and spacing, and pumping levels or rates. Amendments to the

Act in 1982 required that irrigation withdrawals in excess of 100,000 gal/d be reported to the State, although permits for that use still are not required. The Oil and Gas Deep Drilling Act of 1975 authorized the Board of Natural Resources to regulate drilling and use of oil, gas, and other types of wells for the purpose of protecting fresh ground-water supplies. The Georgia Safe Drinking Water Act of 1977 provides for regulation of water quality in public-water systems.

The Georgia Environmental Protection Division (EPD) and its branches are responsible for enforcing all surface-water, ground-water, and water-quality laws. In 1984, a ground-water management plan for Georgia was implemented to identify key activities performed by EPD management, to control and regulate potential pollution sources, and to develop a monitoring program to provide water-quality and water-quantity data on the State's principal aquifers. The Water Resources Management Branch issues permits for ground-water withdrawals that exceed 100,000 gal/d by industrial and municipal users and oversees the reporting of ground-water use for irrigation in excess of 100,000 gal/d. The Ground-Water Program of the Water Protection Branch provides for the permitting of operators of public water-supply systems that use ground water and monitors water quality for compliance with drinking-water standards. The Industrial and Hazardous Waste Management Program of the Land Protection Branch monitors ground water at hazardous waste sites. The Geologic Survey Branch provides technical support for the other branches and has a cooperative program with the U.S. Geological Survey that provides much of the basic data and interpretive information needed to manage the quality and quantity of ground water in the State.

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REFERENCE 3

A Revision of the Lithostratigraphic Units of the Coastal Plain of Georgia

THE MIOCENE THROUGH HOLOCENE

[redacted]

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(1965, p. 15-19), and Scott (1982, p. 137-146) referred to Brooks Sink as a "cotype locality". It is proposed herein that the Brooks Sink section of the Hawthorne, and the core Varnes 1 (W-14280), taken near Brooks Sink (Scott, 1982), also serve as reference localities and hypostratotypes of the Hawthorne Groups.

All of these various sections of the Hawthorne Group in Alachua and Bradford Counties, Florida, are not lithologically representative of the Hawthorne Group in Georgia. However, exposures in the bluffs along the Savannah River from Tiger Leap Bluff in Screven County, to Old Wood Landing in central Effingham County, are lithologically representative of the eastern Georgia Hawthorne Group. Therefore, it is proposed herein that those sections of the Hawthorne Group exposed along the Savannah River in Georgia serve as a composite hypostratotype of the group for eastern Georgia (Fig. 3).

Lithology

The lithology of the Hawthorne Group is dominantly sand and clay. Subordinate lithic components of the Hawthorne Group include dolomite; dolostone; calcite; limestone; phosphorite; phosphate; silica in the forms of claystone (opal-cristobalite), chert, and siliceous microfossils; feldspar; heavy minerals; carbonaceous material and lignite; zeolites; and fossils. Locally, or in beds and lenses, dolostone, limestone, phosphorite, clay, or claystone constitute the dominant lithologies.

The quartz sand component of the Hawthorne Group generally dominates the clay component, but beds or lenses of relatively pure sand are rare in the Hawthorne Group. The sand of the Hawthorne is most commonly fine-grained and well-sorted.

The Hawthorne Group is characteristically argillaceous (see Weaver and Beck, 1977), and the clay occurs in all proportions to the sand. Beds and lenses of clay and sandy clay are common in the Hawthorne, and two members, the Dogtown Clay and Berryville Clay Members, consist principally of clay. Most commonly, however, the clay is interstitial to the sand, and the lithology of the sediment ranges from slightly argillaceous sand to sandy clay. The clay mineral suite of the Hawthorne Group consists of smectite (montmorillonite), illite, palygorskite, sepiolite, and kaolinite (Gremillion, 1965; Weaver and Beck, 1977; Hetrick and Friddell, 1984).

The carbonate content of the Hawthorne Group is variable (also see Weaver and Beck, 1977), being absent in some units and in some sections, and dominating the lithologies of some units in other sections. The most widely occurring and characteristic carbonate mineral of the Hawthorne Group in Georgia is dolomite. Calcite, although locally conspicuous and prominent, is not generally common in the Hawthorne Group in Georgia. Calcite constitutes the greatest proportion of the carbonate in the Hawthorne Group in the Savannah River area and in the continental shelf area. It is characteristic of the Tiger Leap Member of the Parachucla Formation and of the Torreya Formation, and it is locally prominent in the Porters Landing member of the Parachucla Formation and in the Charlton Member of the Coosawhatchie Formation. In all other units and in all other areas in Georgia, dolomite is the characteristic carbonate mineral of the Hawthorne Group.

The carbonate content of the Hawthorne Group generally increases southward across Georgia into Florida, where it is conspicuous in most subdivisions of the Hawthorne. The carbonate content of the Hawthorne also appears to increase seaward in Georgia, but this increase is not as noticeable as the increase in a southward direction. In addition, the dolomite content and proportion generally increase southward (with the exception of the Torreya Formation), and the calcite content tends to increase seaward so that the dolomite content is minor or absent on the continental shelf.

Phosphate is one of the most characteristic lithic components of the Hawthorne Group (also see Weaver and Beck, 1977), and the phosphate content of the group stands in sharp contrast to the nonphosphatic underlying, overlying, and adjacent formations and groups. The phosphate content of the Hawthorne Group is highest in the coastal area of Georgia and on the eastern margins of the Florida Platform. In general, the phosphate content decreases westward and upsection. It is very low or absent in southwestern Georgia and in the upper part of the Hawthorne in the central Georgia Coastal Plain. All of the known phosphate in Georgia consists of small, rounded, black, brown, amber, gray to buff grains or pellets of apatite. There are no known occurrences of hard rock phosphate or pebble phosphate in Georgia.

Siliceous sediments are also characteristic of the Hawthorne Group. Silica is most common in the form of siliceous claystone (opal-cristobalite) and siliceous microfossil-rich (diatoms, radiolarians, and silicoflagellates) sediments. Chert also occurs but is less common, and petrified wood occurs locally and rarely.

Stratigraphic Relationships

The Hawthorne Group underlies perhaps three-quarters of the Coastal Plain of Georgia and is, therefore, one of the most widespread lithostratigraphic units in the state. The western limit of the Hawthorne Group in southwestern Georgia is the Pelham Escarpment (Fig. 13). Farther north, the western limit approximates the Ocmulgee River although Hawthorne outliers occur west of the Ocmulgee River as far north as the vicinity of Hawkinsville in Pulaski County. Its northern limit in the subsurface approximates a trend eastward across Laurens County, central Emanuel County, and Screven County. The northern limit of the Hawthorne Group in Georgia represents a broad and ambiguous zone of facies change, in the subsurface, into the marginal marine to nonmarine Altamaha Formation. The Hawthorne Group extends northward into South Carolina and southward into

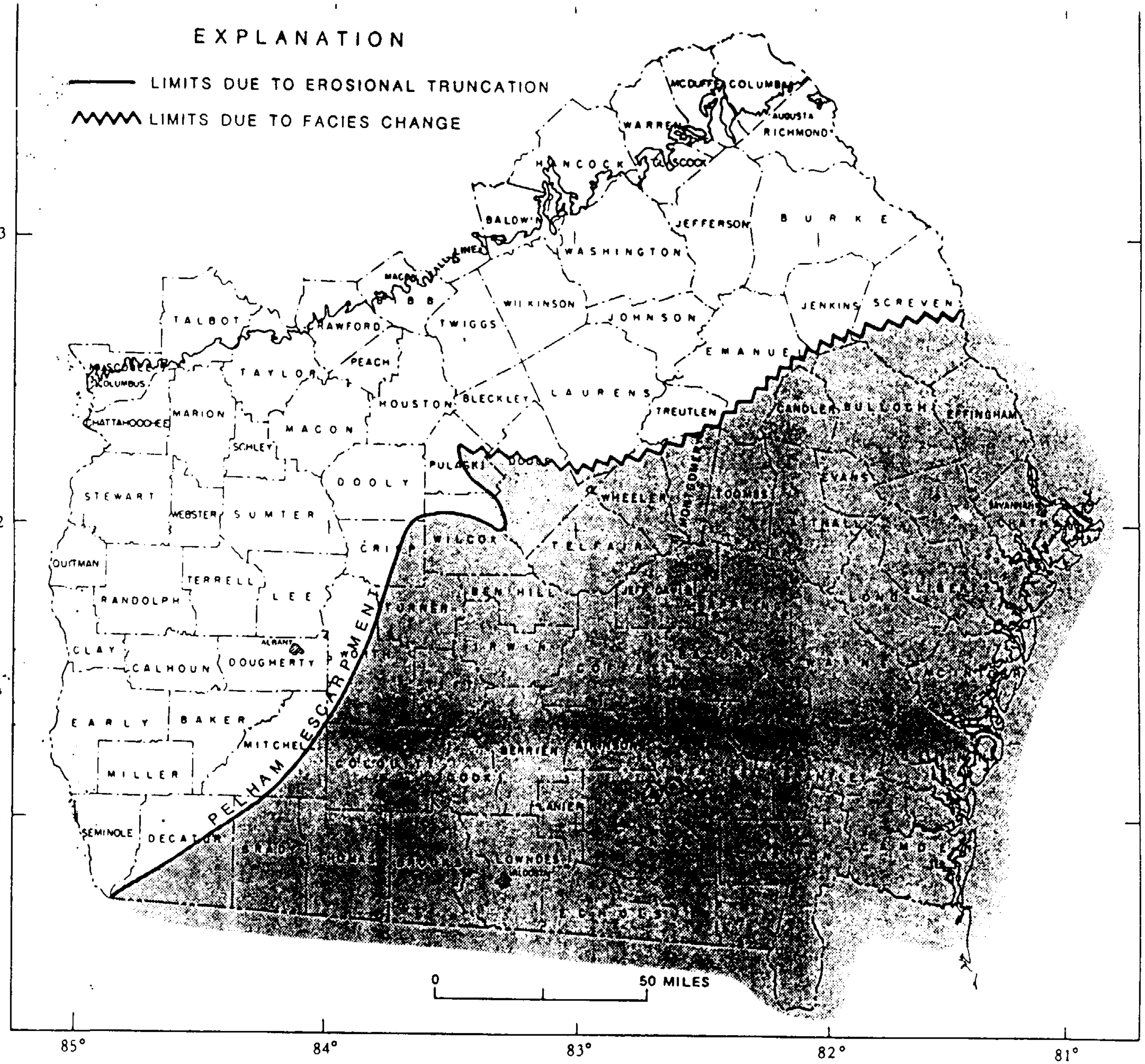

Figure 13. The areal distribution (outcrop and subcrop) of the Hawthorne Group in Georgia.

sandstones and claystones that produce extensive areas of flat rock outcrops and low bluffs (Dall and Harris, 1892, p. 81-82; Veatch and Stephenson, 1911, p. 403-405). Olson (1967) informally called these indurated phases of the Altamaha Formation the Ashburn formation, after exposures of the sandstone cropping out along Interstate 75 north of the town of Ashburn in Turner County, Georgia. The name Ashburn has not been adopted in this report because Ashburn is a junior synonym of the Altamaha Formation, the name has never been formalized, and the indurated phases (Ashburn) are known to be discontinuous in outcrop and cannot be mapped over any large area (also see Georgia Geological Survey, 1976). There is evidence, however, that the lower part of the middle Miocene Altamaha Formation is pervasively indurated in the subsurface, and that the sporadic distribution of outcropping indurated phases of the formation is due to weathering and leaching of the cementing material. At this time, there are few cores that penetrate the entire middle Miocene portion of the Altamaha Formation. In these cores, however (Coffee 3 and 4, GGS-3539, GGS-3541; Berrien 10, GGS-3542; Colquitt 3, GGS-3179; see Fig. 2), the lower part of the Altamaha Formation is consistently indurated. The typical outcropping, middle Miocene Altamaha Formation that occurs in the stratigraphic position of the indurated sediments, consists of weathered, thick-bedded to massive and structureless, sandy clay and argillaceous sand. These weathered sandy clays and argillaceous sands are closely related to the indurated sediments in outcrop. At many outcrop sites, small (as little as 1 x 0.5 foot [30 x 15 cm]) to large (greater than 3 x 1 feet [1 x 0.3 m]) pods of apparently unweathered sandstone are enclosed or surrounded by weathered sands and clays, indicating that the surrounding weathered sediments are weathering products of the indurated sediments (sandstones and claystones). It is likely, therefore, that the typical unweathered, unleached, lower part of the middle Miocene Altamaha Formation consists of argillaceous sandstone and sandy claystone, and that this is the typical unaltered lithology of the lower part of the unit.

A lower, indurated phase is not so readily apparent in the lower Miocene part of the Altamaha Formation. The indurated phases of the lower Miocene do appear to be encountered more in the lower part of the unit or, perhaps more accurately, at lower elevations in the outcrop area. Field studies, in addition to a few cores that penetrate much of the lower Miocene Altamaha Formation (Washington 8, GGS-1179; Washington 10, GGS-1182; Washington 17, GGS-1189; Screven 4, GGS-1007; see Fig. 2), indicate that the indurated phases are not as pervasive as in the middle Miocene, and they tend to be more interstratified with nonindurated sands and clays.

Whereas channel-fill lithologies (cross-bedded sands and gravels) are encountered in the upper part of the middle Miocene Altamaha, channel-fill lithologies occur more randomly throughout the lower Miocene Altamaha. Field observations also indicate that channel-fill lithologies are more closely associated with the indurated phases in the lower Miocene.

The above observations suggest that there are some systematic but subtle differences between the lower Miocene and middle Miocene components of the Altamaha Formation. Particular lithologies are not known to be restricted to either the lower or middle Miocene parts of the Altamaha Formation. However, thick beds of unweathered clay, finely sandy claystone, and claystone that are devoid of sand appear, at this time, to be more characteristic of the lower Miocene Altamaha. Indurated sediments in the middle Miocene Altamaha generally consist of variably argillaceous sandstones or, less commonly, sandy claystones.

The Altamaha Formation is essentially nonfossiliferous. Scattered oyster shell fragments have been reported from the formation at Collins in Tattnall County (Veatch and Stephenson, 1911, p. 406). I have seen evidence of a few burrows in Coffee, Emanuel, and Screven Counties. Small irregular burrows, approximately 1 mm in diameter and constructed of fine-grained sand cemented with siliceous material, are locally abundant in fine-grained sediments of the formation in the Altamaha River area. Presumably these are trace fossils, but they are unlike trace fossils found in other Coastal Plain deposits in Georgia. No other fossils or trace fossils are known from the Altamaha Formation.

Stratigraphic Relationships

The Altamaha Formation is the most widespread outcropping lithostratigraphic unit in Georgia (Fig. 42). Its eastern, or seaward, limit is the Orangeburg Escarpment-Trail Ridge trend in eastern Georgia. The Altamaha Formation grades laterally eastward into the Aquitanian Tiger Leap Member of the Parachucla Formation (Hawthorne Group) in the vicinity of the Orangeburg Escarpment in the Savannah River area (Pl. 2). In the Southeast Georgia Embayment region south of Bulloch County, the Altamaha Formation grades laterally eastward into the middle Miocene Ebenezer Member of the Coosawhatchie Formation of the Hawthorne Group in the vicinity of the Orangeburg Escarpment in the north and Trail Ridge in the south (Fig. 11). The updip limits of the Altamaha Formation in Georgia extend from northern Burke County in the east, westward through Jefferson, Washington, northern Laurens, and southeastern Twiggs Counties. Farther south, the updip limits of the Altamaha Formation are in the vicinity of the Ocmulgee River in the north, and the Pelham Escarpment in the south (Fig. 42). The southern limit of the Altamaha Formation approximates a line (or zone of facies change) that extends from Ware County in the east through Colquitt County in the west. East of the vicinity of Cook and Lowndes Counties, the Altamaha Formation appears to grade laterally southward into the Statenville Formation of the Hawthorne Group. West of the Little River, the Altamaha Formation appears to thin and pinch out in a southward direction in Colquitt County. The Altamaha Forma-

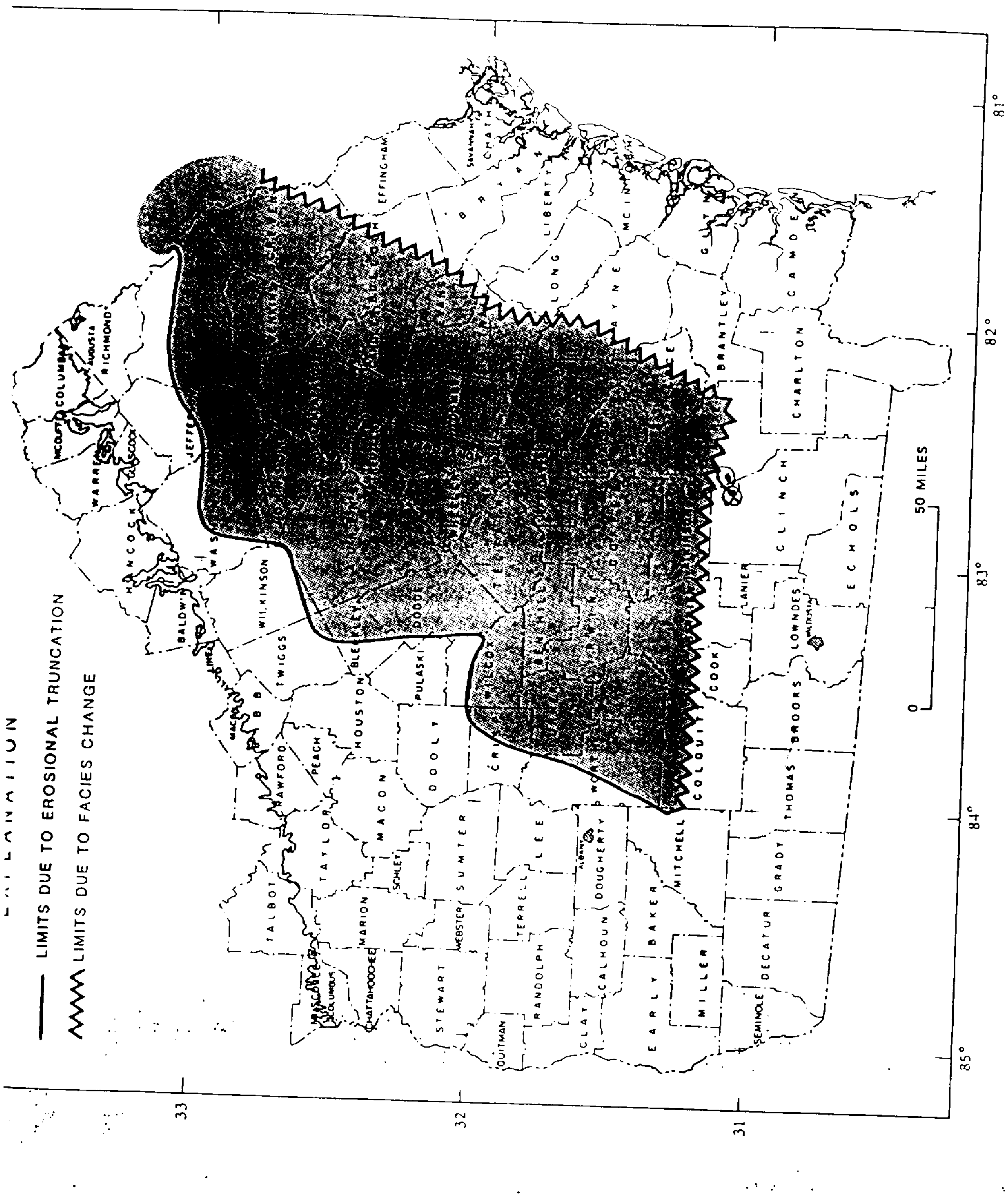

Figure 42. The areal distribution (outcrop and subcrop) of the Altamaha Formation in Georgia.

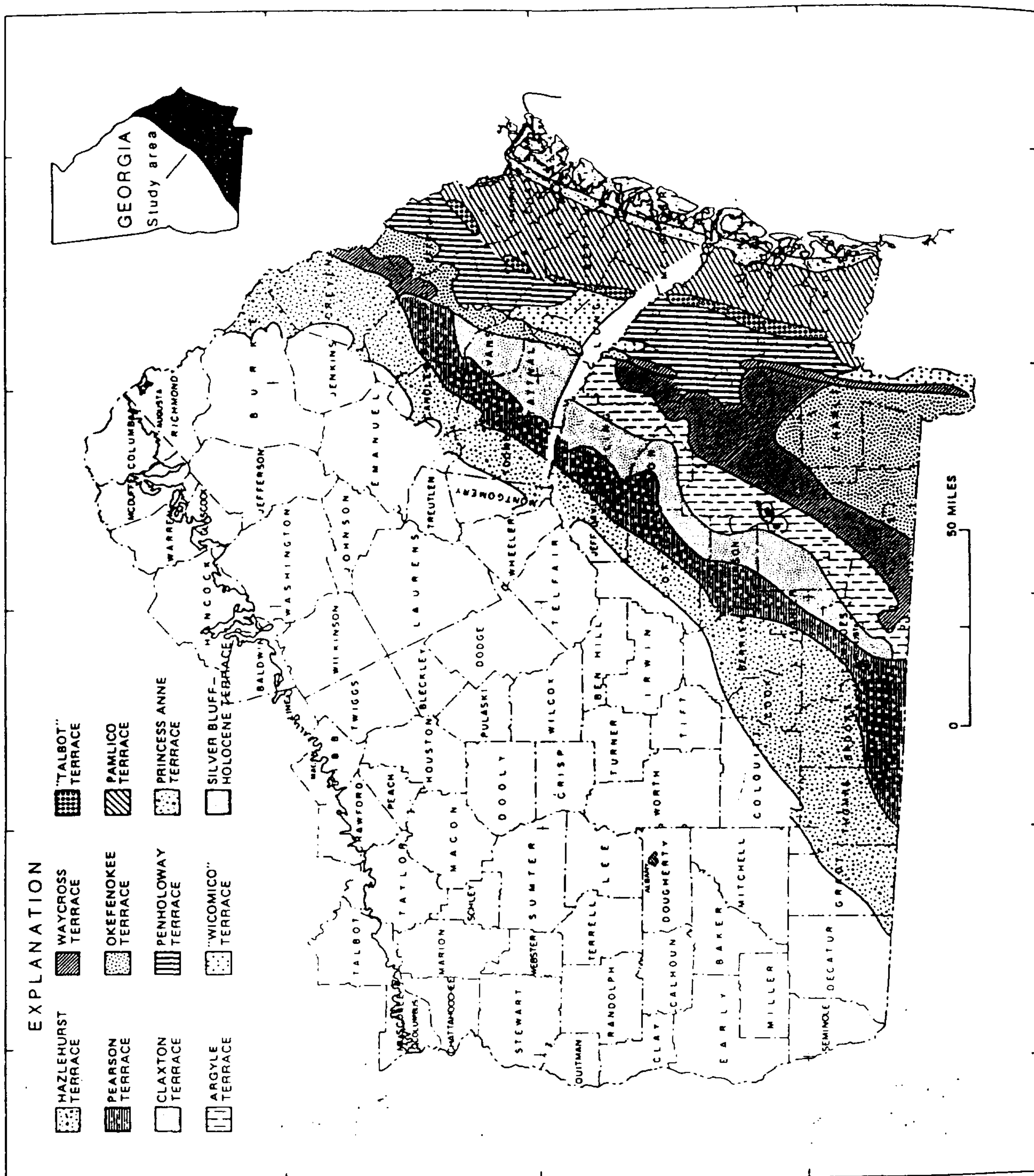

Figure 56. Generalized map of the marine terraces and the dissected marine terrace region of Georgia.

ı from the south. In contrast, all of the lower
ıtems in Georgia are more strongly developed near r rivers, and become more weakly developed .he major rivers, suggesting that their sources of : the major rivers.

:per terraces consist of the Argyle, Claxton, Pear- Hazlehurst (Fig. 56). These marine terraces are -ized, in Georgia, both by the absence of emergent ıands, barrier island-like ridges, back-barrier tracts, ciated deposits, and also by the simplicity of their ogy. The Argyle and Claxton terraces have rela- ge expanses of undissected terrain, but the Pearson :lehurst terraces are deeply dissected in most areas, :ly a few remnants of undissected terrace still d.

najor terraces are separated by regular elevation s of approximately 25 feet (7.6 m) (i.e., the sea level hat resulted in the construction of the major terraces parated by intervals of approximately 25 feet [7.5 ascending order of age or elevation, these sea level ınd the resulting terraces are the following: Pamlico [7.6 m]), "Talbot"(50 feet [15 m]), Penholoway (75 :.5 m]), Okefenokee (125 feet [37.5 m]), Waycross :t [46 m]), Argyle (175 feet [53 m]), Claxton (200 feet), Pearson (225 feet [68.5 m]), and Hazlehurst (275 • m]). The only exceptions to this progression are the mico" sea level stand at between 90 and 95 feet (27.5 m), and the absence of evidence for a sea level stand roximately 250 feet (76 m) above sea level. The Silver ınd Princess Anne appear to represent minor sea level ; in that these terraces are poorly developed or absent rine terrace regions outside of the Sea Island district.

ussion

ɔcene-Silver Bluff terrace complex

e Holocene and the Silver Bluff (Cooke, 1945, p. 248; Neil, 1950) represent two different and distinct coastal :ruction events but are combined in this study because ıilver Bluff terrace was largely reoccupied by the Holo- transgression and its terracing event. The Silver Bluff ɪh was reoccupied by the Holocene marsh, and the ɔcene barrier islands are merely a continuation of the :r Bluff barrier islands. The two terrace construction ıts, therefore, have merged, producing one marine ter- . The Holocene component of the terrace includes the ɛnt day barrier islands that have been constructed ınst the seaward faces of the Silver Bluff barrier islands, ɛpt in the vicinity of the Savannah and Altamaha Rivers :re the Holocene marsh and barrier islands have been structed seaward of the Silver Bluff barrier islands. The locene barrier islands are characterized by prominent dern dune development, in contrast to the subdued ɔography on the Silver Bluff barrier islands that are ɹoid of sand dunes. Only the greater topographic relief on : Holocene, because of continuing dune construction, serves to distinguish the Holocene component from the topographically more subdued Silver Bluff. In addition, the Silver Bluff marsh stands slightly higher than the Holocene marsh and generally is inundated only during the highest tides.

Holocene and Silver Bluff barrier islands are equally developed along the coast of Georgia with little or no distinction in styles of construction between those barrier islands adjacent to the major rivers and those distant from the major rivers.

The summit elevations of the Holocene barrier islands range from near sea level to approximately 45 feet (14 m) at the crests of the highest sand dunes. The average summit elevations of the Holocene islands typically are between 10 and 20 feet (3 to 6 m). The width of the Holocene marsh typically ranges from 3 to 6 miles (5 to 9.5 km). The elevation of the back-barrier tract is sea level to approximately 7 feet (2 m) above sea level.

Sea level during the Silver Bluff construction event stood at approximately 6 feet (1.8 m) above present sea level. The summit elevations of the Silver Bluff barrier islands typically range from 10 to 20 feet (3 to 6 m) with some localized elevations being in excess of 40 feet (12 m). Elevations on the Holocene-Silver Bluff terrace complex range from near sea level to 45 feet (14 m), a relief of more than 45 feet (14 m), including sub-sea level elevations of tidal channels.

The Holocene-Silver Bluff terrace complex is directly underlain by the Satilla Formation.

Princess Anne terrace complex

The Princess Anne (Hails and Hoyt, 1969) terrace complex bears the same relationship to the Pamlico terrace that the Holocene bears to the Silver Bluff (i.e., the Princess Anne marsh largely reoccupied the Pamlico marsh, and Princess Anne barrier islands, in most instances, were constructed against the seaward faces of the older Pamlico barrier islands). Princess Anne back-barrier tracts (marshes), as distinct from those of the reoccupied Pamlico back-barrier tracts, are very poorly developed or lacking in Georgia.

The emergent Princess Anne barrier islands are almost equally developed along the coastal area of Georgia with only slightly more prominent development near the major streams.

Sea level during the Princess Anne terrace construction event stood at approximately 13 feet (4.0 m). The summit elevations of the Princess Anne barrier islands range from approximately 15 to 25 feet (4.5 to 7.6 m) whereas the elevations of the suspected back-barrier tracts, where developed, range from approximately 10 to 20 feet (3 to 6 m) above sea level. Elevations on the Princess Anne terrace complex, therefore, range from approximately 10 to 25 feet (3 to 7.6 m), a range of 15 feet (4.5 m).

The Princess Anne terrace complex is directly underlain by the Satilla Formation.

present sea level. This conclusion is consistent with (1) the scattered back-barrier tracts at 80 to 95 feet (24 to 29 m) in Georgia, (2) the elevations of the well-developed "Wicomico" back-barrier tracts of 80 to 90 feet (24 to 27 m) in South Carolina, and (3) the elevation of approximately 90 to 95 feet (27 to 29 m) of a prominent scarp along the Gulf of Mexico in northwestern peninsular Florida.

In South Carolina and perhaps in northeastern Florida, the summit elevations of the "Wicomico" barrier islands range from approximately 95 to 105 feet (29 to 32 m). The elevations of the "Wicomico" back-barrier tracts typically range in elevation from approximately 80 to 95 feet (24 to 29 m). The relief on the "Wicomico" terrace complex, therefore, appears to be approximately 25 feet (7.5 m).

The "Wicomico" terrace in Georgia is directly underlain by the Cypresshead Formation.

Okefenokee terrace (redefined)

The name Okefenokee terrace was first used by Veatch and Stephenson (1911), expanded on by Cooke (1925), and abandoned by Cooke (1931). MacNeil (1950) reintroduced the concept of the Okefenokee in a geomorphologic sense when he recognized an Okefenokee "shoreline" at an elevation of 150 feet (46 m). By implication, the Okefenokee terrace (not referred to as such by MacNeil, 1950) occupied the terrain between the scarp at 150 feet (36 m) and the presumed shoreline at 100 feet (30 m). There is also, however, a low scarp at 125 feet (38 m), not recognized by MacNeil (1950), that bounds the Okefenokee Swamp on the west. As a result, this author proposes a modification of the scheme introduced by MacNeil (1950). The terrain bounded by the scarp at 150 feet (46 m) and by the "Wicomico" terrace (sea level stand at approximately 90 to 95 feet) is divided into two terraces in this report. The upper of the two terraces is herein referred to as the Waycross terrace. It is bounded on the landward (western) side by a low scarp at approximately 150 feet (46 m) (Okefenokee shoreline of MacNeil, 1950). The lower of the two terraces is herein referred to as the Okefenokee terrace because the greater part of that terrace in Georgia is occupied by the Okefenokee Swamp. The Okefenokee terrace is bounded on the landward (western) side by a low scarp at approximately 125 feet (38 m).

The Okefenokee terrace is a composite terrace in Georgia. In the northern area, between the vicinity of Jesup and the Savannah River, it has simple terrace morphology, but in the southern area, in the Okefenokee basin, it has both simple and complex morphology. In the northern area, the Okefenokee terrace is restricted to the region east of the Orangeburg Escarpment (Fig. 56). In the southern area, it is found only west of Trail Ridge and south of the Satilla River. In this southern area, the Okefenokee terrace consists of a very wide back-barrier tract up to 30 miles (50 km) across that is now mainly occupied by the Okefenokee Swamp (Fig. 58). The Okefenokee terrace is bounded on the east by the eastern flanks of Trail Ridge, and on the north by a complex of anomalous sand ridges included in the Waycross Ridge. Trail Ridge and the associated Waycross Ridge are older features that were reoccupied during the Okefenokee stand of sea level. Trail Ridge may have been added to during the construction of the Okefenokee terrace, but the only sand ridges in Georgia that appear to have been constructed during the formation of the Okefenokee terrace are an obscure set of ridges paralleling and immediately south of Waycross Ridge. There is no development of barrier islands or sand ridges in the northern segment of the Okefenokee terrace in Georgia. There is no evidence that the Okefenokee terrace was ever present between the Okefenokee Swamp in Charlton County and the vicinity of Jesup in Wayne County (Fig. 56).

Sea level during the Okefenokee terrace construction event stood at approximately 125 feet (38 m). The typical elevations on the Okefenokee terrace range from 110 feet to 120 feet (33.5 m to 36.5 m). On the obscure associated sand ridges, summit elevations range from 120 to 130 feet (36.5 to 40 m), whereas on Trail Ridge, summit elevations range from approximately 135 feet to 175 feet (41 m to 53 m).

Between the Canoochee and Savannah Rivers, there are some remnants of extremely flat terrain with elevations between 95 and 105 feet (29 and 32 m). In this report, this terrain is included in the Okefenokee terrace because it is continuous in several places with surfaces of typical Okefenokee elevations. The total relief on the Okefenokee terrace complex, therefore, is approximately 80 feet (24 m).

In its northern segments, the Okefenokee terrace in Georgia is directly underlain by the Cypresshead Formation. The eastern part of the southern segment (i.e., the eastern part of the Okefenokee swamp), is directly underlain by swamp deposits or the Cypresshead Formation. The southwestern part of the southern segment is directly underlain by the Statenville Formation of the Hawthorne Group.

Waycross terrace (new name)

The Waycross terrace is a new terrace name proposed herein for that marine terrace that is bounded on the landward side by a low scarp at approximately 150 feet (46 m), and on the seaward side by the scarp at approximately 125 feet 38 m). Typical elevations on the Waycross terrace range from 130 to 140 feet (40 m to 43 m). The name Waycross is taken from the town of Waycross in Ware County, Georgia, that is built on the Waycross terrace.

The Waycross terrace of this report is the upper part of the Okefenokee terrace of Cooke (1925), and the scarp at 150 feet (46 m) is the Okefenokee shoreline of MacNeil (1950).

The Waycross terrace is a composite terrace in Georgia (i.e., it occurs with both simple terrace morphology and complex terrace morphology). Like the Okefenokee terrace, the Waycross terrace occurs in two different areas in Georgia; the southern segment includes Trail Ridge, Waycross d Lake City Ridge and a large expanse west of the .ee terrace (Fig. 56). The northern segment occurs : Orangeburg Escarpment in Bulloch, Effingham, ven Counties, Georgia. The northern segment and :rn part of the southern segment of the Waycross re morphologically simple. However, Trail Ridge e eastern limit of the Waycross terrace in Brantley yne Counties. South of Brantley County, Trail separated from the rest of the Waycross terrace by enokee terrace, a large embayment in the Waycross Fig. 56).

Ridge is the highest and most massive barrier island-d ridge in Georgia (also see Cooke, 1925; MacNeil, :rkle, 1972). Its summit elevations, in Georgia, range 35 feet to 175 feet (41 to 53 m). Farther south in ι, the summit of Trail Ridge reaches elevations of 250 › m). In the past, Trail Ridge had been placed in the :land terrace (Cooke, 1943; 1945), and in the "Wico-terrace (Hails and Hoyt, 1969; Mann, 1974; Georgia gical Survey, 1976), and associated with the scarp at :t (46 m) (MacNeil, 1950). Trail Ridge is considered to art of the Waycross terrace of this report because (1) mmit elevations of Trail Ridge (140 feet to 175 feet [43 53 m]) in Georgia are compatible with elevations ted of the Waycross terrace and (2) Trail Ridge in ley and Wayne Counties occurs adjacent to and east ard) of the Waycross terrace surface, the standard guration for a barrier island, back-barrier system (Fig. n addition, the Okefenokee terrace lies east (seaward) ail Ridge in northern Wayne County, thus bracketing errace relationships of Trail Ridge.

arther evidence that Trail Ridge is not a part of the comico" terrace is the occurrence of "Wicomico" back-ier east (seaward) of Trail Ridge in southern Charlton inty, between Trail Ridge and the St. Marys River (Fig. In addition, the Waycross Ridge, which must have been structed during construction of the Waycross terrace ause it lies directly on the Waycross surface and shows geographic relationship to older or younger terraces, is a .r of Trail Ridge and has similar summit elevations (135 150 feet [41 to 46 m]). Furthermore, Trail Ridge and its ırs, the Waycross Ridge in Georgia and the Lake City dge in Florida, must have been reoccupied at least one ıe during the Pleistocene sea level fluctuations in the gion. Trail Ridge, it appears, was reoccupied during the kefenokee stand of sea level. Since both "Wicomico" and nholoway back-barrier tracts abut Trail Ridge on the st, the ridge evidently served locally as a shoreline during nstruction of these terraces.

Additional evidence that Trail Ridge is part of the Way-oss comes from Pirkle and Czel (1983), who reported acrofossils from elevations of 132 feet to 161 feet (41 m to 9 m) above sea level in cores from the southern part of Trail Ridge in Georgia. This finding is largely compatible with a eal level stand at approximately 150 feet (46 m). Fossil occurrences up to 11 feet (3.3 m) above the Waycross sea level stand could be attributed to extreme, but not unusual, tidal ranges or storms. Finally, it is possible, but less likely, that Trail Ridge construction could have been initiated to the south in Florida, where the summit elevations on the ridge reach 250 feet (76 m), during an earlier and higher stand of sea level. If the construction was initiated in Florida, the Trail Ridge was possibly not just reoccupied during successive high stands of sea level, but may also have been constructed through increments during these various high stands of the sea.

The Statenville Formation of the Hawthorne Group directly underlies the Waycross terrace in Georgia near the Florida state line, and the Screven Member of the Altamaha Formation or the Cypresshead Formation directly underlies the terrace surface north of the vicinity of Waycross. Trail Ridge in Georgia is constructed on the Cypresshead Formation. The Cypresshead Formation also directly underlies the Waycross terrace surface (or the undifferentiated surficial sands that mantle its surface) in its northern segment in Bulloch, Effingham, and Screven Counties.

Argyle terrace (new name)

The Argyle terrace is a new terrace name proposed herein for that marine terrace that is bounded on the landward side by the low scarp at approximately 170 to 175 feet (52 to 53 m) above sea level, and on the seaward side by the low scarp at approximately 150 feet (46 m). Typical elevations on the Argyle terrace range from approximately 155 to 165 feet (47 to 50 m). The Argyle terrace and all of the higher terraces in Georgia are morphologically simple (i.e., they are gently inclined surfaces bounded by low, presumably wave-cut scarps, and they do not have associated emergent barrier islands, sand ridges, or back-barrier tracts). The name Argyle is taken from the community of Argyle in northern Clinch County, Georgia, where the Argyle terrace is typically developed and upon which the village of Argyle is located.

The Sunderland terrace of Cooke (1930a, 1930b, 1931) includes the Argyle, Waycross, and Okefenokee terraces of this report, and the Argyle terrace approximates the upper part of the Sunderland terrace. Sunderland as a terrace name is considered to be inappropriate in this report because the name Sunderland was originally applied to the Sunderland formation, a lithostratigraphic unit, in Maryland (Shattuck, 1901, 1906).

The scarp that bounds the Argyle terrace on the west is easily traceable only in the expanse of undissected terrain west of the Okefenokee Swamp in Georgia, between the Alapaha and Satilla Rivers. North of the Satilla River, the Argyle terrace and scarp at 170 to 175 feet (52 to 53 m) are traceable with difficulty due to the dissection of the terrace surface by incision and erosion by the Satilla River system.

The Argyle terrace occurs only as far north as the Altamaha River in Georgia (Fig. 56). Farther north, the Argyle terrace elevations occur only in the face of the Orangeburg

Escarpment (i.e., the terraces in front, or east, of the Orangeburg Escarpment are lower in elevation and younger than the Argyle terrace, and the marine terraces behind, or west or, the Orangeburg Escarpment are higher in elevation and older than the Argyle) (see Fig. 57). The Argyle terrace re-emerges on the east side of the Orangeburg Escarpment farther north in South Carolina.

Near the Florida state line in Echols and Lowndes Counties, the Argyle terrace is directly underlain by the Statenville Formation of the Hawthorne Group, or by the Miccosukee Formation. From the vicinity of the Satilla River to the Altamaha River, the Argyle terrace is directly underlain by the Screven Member of the Altamaha Formation. In northern Wayne County, however, the Argyle terrace is directly underlain by the updip feather-edge of the Cypresshead Formation.

Claxton terrace (reintroduced)

The Claxton terrace of Cooke (1925, p. 29) is reintroduced in this report and is that marine terrace bounded on the shoreward (west) side by the low scarp at approximately 200 feet (61 m) and bounded on the seaward (east) side by the low scarp at approximately 170 to 175 feet (52 to 53 m). Typical elevations on the Claxton terrace range from 180 to 190 feet (55 to 58 m).

The surface of the Claxton terrace is more dissected than that of the lower, younger terraces. South of the Altamaha River, well-preserved and undissected Claxton terrace is still present in eastern Lowndes, Lanier, Clinch, Atkinson, Bacon, and Appling Counties. North of the Altamaha River, it is present in Tattnall and Evans Counties, the type area of the Claxton terrace of Cooke (1925).

The Claxton terrace occurs as a band from Lowndes County in the southwest, to Evans County in the northeast (Fig. 56). The Claxton terrace is not present in Georgia north of the Canoochee River, but it re-emerges on the east side of the Orangeburg Escarpment farther north in South Carolina.

The Claxton terrace is directly underlain by the Miccosukee Formation in Lowndes County, and by the Altamaha Formation north of the vicinity of the Satilla River. No information on the underlying formations is available between Lowndes County and the Satilla River.

Pearson terrace (new name)

The Pearson terrace is a new terrace name proposed herein for that marine terrace that is bounded on the landward side by the low scarp at approximately 225 feet (68 m), and on the seaward side by the low scarp at approximately 200 feet (61 m). Like the other upper terraces, the Pearson is morphologically simple. Typical elevations on the Pearson terrace range from 205 to 220 feet (62.5 to 67 m). The name Pearson is taken from the town of Pearson in Atkinson County, Georgia, which is located on the somewhat dissected seaward scarp bounding the Pearson terrace.

The Coharie terrace of Cooke (1930a,1930b,1931) (also called the Coharie formation [Cooke, 1936, 1943,1945], was postulated to occur between the shorelines at 170 feet and 215 feet. However, with modern 1:24,000-scale map coverage and contour intervals of 5 feet (1.5 m), no scarp at 215 feet (65.5 m) can be recognized. At that elevation, the terrace surface is flat or gently inclined. On the other hand, Stephenson (1912) originally defined the inner edge of the Coharie formation as occurring at elevations between 220 and 235 feet (67 and 71.5 m), a determination that is consistent with my observations for the inner margin of the Pearson terrace in Georgia and South Carolina. As a result of the above modifications, the Coharie terrace of Cooke (1930a, 1930b, 1931) is divided into two parts in this report, a lower Claxton terrace and an upper Pearson terrace. Coharie as a terrace name is considered inappropriate because the name Coharie was originally applied to the Coharie formation, a lithostratigraphic unit, in North Carolina (Stephenson, 1912, p. 29).

The scarp, at approximately 225 feet (68 m), is considerably more dissected and ambiguous than the lower scarps. Only in northwestern Atkinson County is the low scarp still preserved and well developed. Elsewhere, its earlier existence is inferred from the relatively abrupt and systematic increase in interfluve summit elevations from approximately 200 feet (67 m) to 230-240 feet (70 to 73 m).

Relatively large expanses of undissected Pearson terrace surface still exist only in western Atkinson, northwestern Clinch, and northeastern Lanier Counties, between the Satilla and the Alapaha Rivers. Smaller remnants of the terrace occur in Appling, Tattnall, and Evans Counties. Elsewhere, this terrace is deeply dissected and can be traced only with difficulty by comparing interfluve summit elevations.

The Pearson terrace extends from southeastern Thomas County in the southwest, where it is very deeply dissected, to Bulloch County in the northeast, where it is also very deeply dissected (Fig. 56). The Pearson terrace, like the other upper terraces, occurs only west of the Orangeburg Escarpment, Trail Ridge, and the Okefenokee Swamp in Georgia. It emerges on the east side of the Orangeburg Escarpment in South Carolina.

The Pearson terrace is directly underlain by the Miccosukee Formation in Lowndes, Brooks, and Thomas Counties, and is underlain by the Altamaha Formation north of the Satilla River. No information is available on the underlying formations between Lowndes County and the vicinity of the Satilla River.

Hazlehurst terrace, (reintroduced)

The Hazlehurst terrace of Cooke (1925, p. 29) is reintroduced in this report for that marine terrace bounded on the shoreward side (west) by a generally dissected scarp at approximately 275 feet (84 m), and on the seaward side (east) by the low scarp at approximately 225 feet (68 m). The

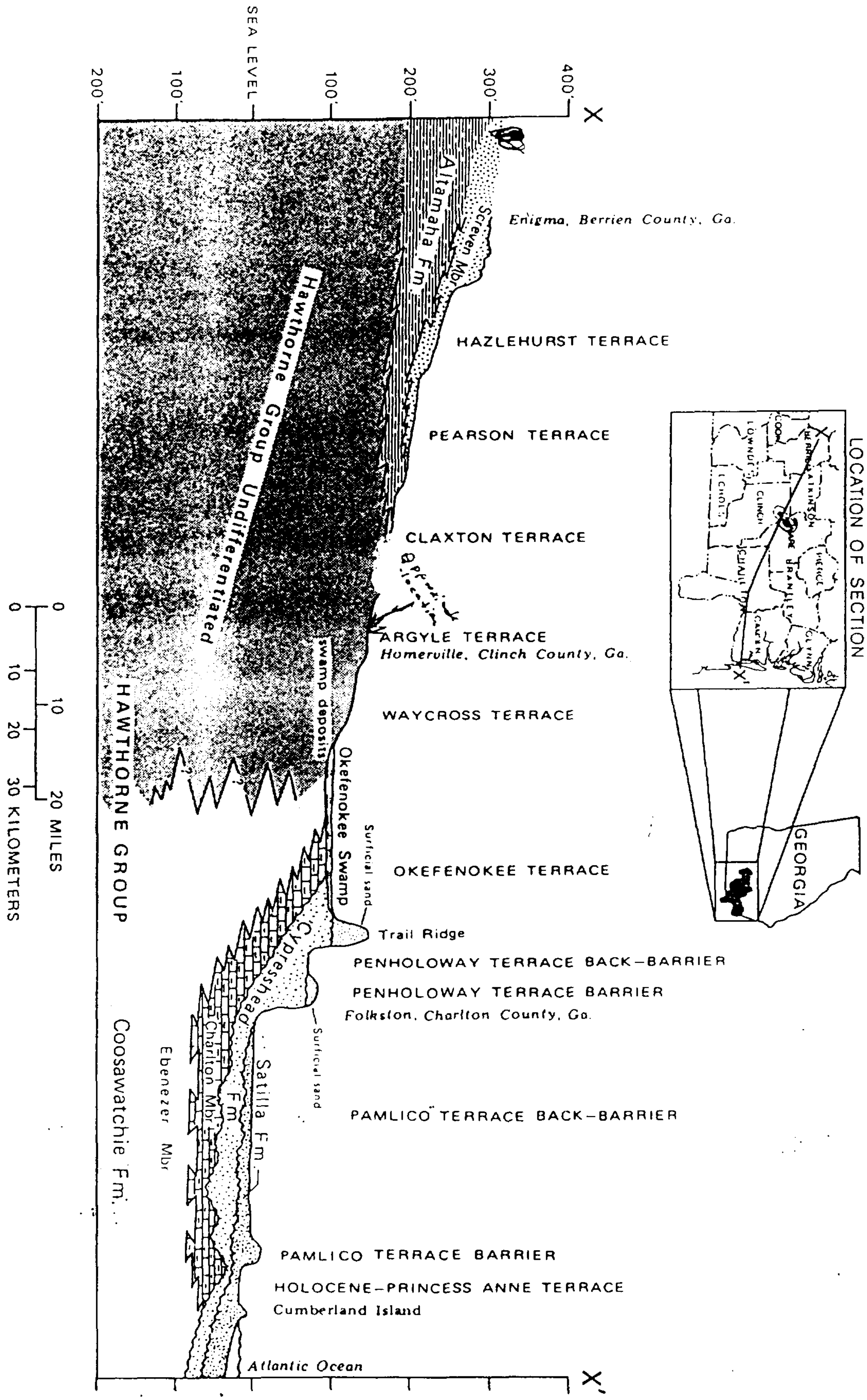

Figure 58. Schematic stratigraphic cross-section of the marine terraces from northern Berrien County to Cumberland Island.

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REFERENCE 4

Hydrogeologic Framework of the Floridan Aquifer System in Florida and in Parts of Georgia, Alabama, and South Carolina

By JAMES A. MILLER

REGIONAL AQUIFER-SYSTEM ANALYSIS

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interfinger with clastic materials or have been weathered into a clayey residuum and (2) in western Alabama and much of the Florida panhandle, where the upper Eocene section consists mostly of fine clastic sediments. The late Eocene represents the most extensive and widespread transgression of Tertiary seas in the Southeastern United States.

The extent, configuration of the top, and area of outcrop of rocks of late Eocene age are shown on plate 8. In Alabama and the southwesternmost corner of Georgia, these rocks are found farther gulfward than the middle Eocene strata that they overlie in offlap relation. From Stewart County, Ga., northeast, however, upper Eocene strata overlap older beds. This onlap relation extends into part of South Carolina.

From an altitude of more than 400 ft above sea level in their area of outcrop in Georgia and South Carolina, upper Eocene beds generally slope gently seaward (pl. 8). This slope is interrupted in northern peninsular Florida by a widespread high area upon which the top of upper Eocene rocks rises to altitudes slightly above sea level. This high area has been called the Ocala uplift, but it is not a true uplift. Even though this feature appears as a high on the upper Eocene top, it is not a structural high on the tops of older units (compare pl. 8 with pls. 3, 4, and 6). The upper Eocene may be high on the Ocala "uplift" because of either (1) deposition of an anomalously thick section of upper Eocene rocks in this area, (2) differential compaction, or (3) postdepositional erosion. The Ocala "uplift," regardless of its origin, is not related to the Peninsular arch. The fact that the effect of the Peninsular arch is not apparent on maps of the top of upper Eocene or younger rock shows that the arch ceased to be an active structure after middle Eocene time.

Some of the major structural lows in the study area, however, continued to actively subside during late Eocene time. Plate 8 shows a steep slope on the upper Eocene top in westernmost panhandle Florida and southern Alabama that reflects the influence of the Gulf Coast geosyncline. The negative area in Gulf and Franklin Counties in panhandle Florida is the Southwest Georgia embayment, and the low centered in Glynn County, Ga., is the Southeast Georgia embayment. The South Florida basin is also shown on plate 8 as a low area in southwestern peninsular Florida. The poor definition of the unnamed low area in east-central Georgia and its contiguous high in South Carolina (pl. 8) indicate that these features were not active "warps" in the late Eocene.

There are a number of small- to medium-sized faults shown on plate 8 that first occur in the late Eocene. Most of these are in central and northern peninsular Florida. Like the Gulf Trough graben system (running northeast across central Georgia on pl. 8), which affects only middle Eocene and younger rocks, these faults in central and northern Florida appear to be shallow features that die out with depth. The locations of the small faults are better known, and the topography shown on plate 8 for the upper Eocene top is more deatailed than that shown for deeper horizons because upper Eocene strata provide a prolific source of ground water and are therefore more intensively drilled than older units.

Upper Eocene rocks crop out more extensively than any other Tertiary unit except the Miocene. In much of their updip outcrop area, they consist largely of calcareous clastic rocks. In southwestern Georgia, easternmost Alabama, and contiguous counties in Florida, uppermost Eocene rocks consist of soft to well-indurated limestone that has a thin to moderately thick (less than 10 to more than 50 ft) clayey residuum developed on it. This residuum masks and subdues the karst topography that drilling shows is developed on the limestone surface there. In western peninsular Florida, upper Eocene sediments consist mostly of highly fossiliferous, soft limestone that shows a highly irregular, karstic, often cavernous surface resulting from extensive dissolution of the rock. Locally, in parts of the Florida peninsula, upper Eocene rocks have been completely removed by erosion, and rocks of middle Eocene age are exposed through the late Eocene surface (pl. 8).

The maximum measured depth to the top of the upper Eocene is about 3,380 ft below sea level in well ALA-BAL-30 in southern Baldwin County, Ala. The maximum contoured depth is about 4,000 ft, just to the southwest of this well. The top of rocks of late Eocene age is more than 1,000 ft below sea level in the Southwest Georgia embayment, more than 700 ft in the Southeast Georgia embayment, and more than 1,200 ft in the South Florida basin. In north-central Florida, the upper Eocene top is at or slightly above mean sea level over a wide area and slopes seaward in all directions from this high. Locally, the upper Eocene top has been vertically displaced as much as 300 ft across some of the small faults that cut the unit.

The thickness of upper Eocene strata is shown on plate 9. In contrast with older Tertiary units, upper Eocene beds are comprised of carbonate rocks almost everywhere. Most of the contouring on plate 9 is based on well-point data. In areas of sparse well control, the thickness of rocks of late Eocene age has been estimated by subtracting contoured structural surfaces of the middle and upper Eocene (pls. 6, 8). The upper Eocene is generally 200 to 400 ft thick, with two major exceptions. In the Southwest Georgia embayment, these rocks are more than 800 ft thick, and in the central part of peninsular Florida, they are less than 100 ft thick in an area that trends east-west across the peninsula. There is much local variation in the thickness of the upper Eocene because of the effects of erosion and (or) dissolution of these rocks, especially in and near the places where they crop out.

OCALA LIMESTONE—Dall and Harris (1892) applied the name Ocala Limestone to the limestone exposed in quarries near Ocala in Marion County, Fla. These rocks were incorrectly correlated with strata in Alabama that were thought then to be Eocene but that are now known to be of Oligocene age. Cooke (1915) was the first to assign the Ocala to its correct upper Eocene stratigraphic position. Applin and Applin (1944) divided the Ocala into upper and lower members. This twofold division of the formation is still used by the U.S. Geological Survey at the time of this writing (1984). However, the Florida Bureau of Geology considers the Ocala to be a group consisting of, in ascending order, the Inglis, Williston, and Crystal River Formations, as Puri (1953b) proposed.

Puri's three formations cannot be recognized lithologically even at their type sections and cannot be differentiated in the subsurface. This author does not consider the Inglis, Williston, and Crystal River Formations to be either readily recognizable nor mappable, and the terms are not used in this report. As Applin and Applin (1944) recognized, the Ocala consists in many places of two different rock types. The upper part of the Ocala is a white, generally soft, somewhat friable, porous coquina composed of large Foraminifera, bryozoan fragments, and whole to broken echinoid remains, all loosely bound by a matrix of micritic limestone. This coquina is the typical Ocala of the literature and comprises much of the formation. The lower part of the Ocala consists of cream to white, generally fine grained, soft to semi-indurated, micritic limestone containing abundant miliolid remains and scattered large foraminifers. Locally, in southern Georgia, the lower part of the Ocala is slightly glauconitic. This lower fine-grained facies of the Ocala is not everywhere present and may locally be dolomitized wholly or in part. In southern Florida, the entire Ocala is composed of micritic to finely pelletal limestone in places. Because the twofold division of the Ocala is not everywhere recognizable and because the lower micritic unit is thin where it occurs, the two members are not differentiated in this report.

The Ocala Limestone is found throughout Florida (except where it has been locally removed by erosion) and underlies much of southeastern Alabama and the Georgia coastal plain. The Ocala is one of the most permeable rock units in the Floridan aquifer system. The surface of the formation is locally very irregular as a result of the dissolution of the limestone and the development of karst topography. Locally, the upper few feet of the Ocala in the subsurface consist of white, soft, clayey residuum. Where the formation is exposed at the surface, such residuum may also be present (as in southwestern Georgia), but the clayey material is ocher to red there owing to the oxidation of the small amounts of iron that it contains.

Fauna considered characteristic of the Ocala Limestone include the Foraminifera *Amphistegina pinarensis cosdeni* Applin and Jordan, *Lepidocyclina ocalana* Cushman, *L. ocalana floridana* Cushman, *Eponides jacksonensis* (Cushman and Applin), *Gyroidina crystalriverensis* Puri, and *Operculina mariannensis* Vaughn. Although the foraminiferal genus *Asterocyclina* is not restricted to the late Eocene, it usually is not found above the top of the Ocala in the study area. The Ostracoda *Cytheretta alexanderi* Howe and Chambers and *Jugosocythereis bicarinata* (Swain) are found in shallower water parts of the Ocala as well as in its clastic equivalents.

MOODYS BRANCH FORMATION—In western panhandle Florida, the Ocala thins and, although the upper part of the formation retains its typical coquinoid character, the lower part grades westward into soft gray clay and minor interbedded fine-grained sand. This lithology is correlative with the outcropping Moodys Branch Formation of western Alabama, which consists of greenish-gray, calcareous, glauconitic sand and clay and a few layers of sandy limestone.

YAZOO CLAY—The upper part of the Ocala in central Alabama grades northward and westward through a white, massive, fine-grained, clayey, glauconitic limestone into the outcropping Yazoo Clay in western Alabama and eastern Mississippi. The Yazoo can be locally divided into four members (Murray, 1947), (from oldest to youngest): (1) the North Twistwood Creek Clay, a bluish-gray, sandy, slightly calcareous, fossiliferous clay; (2) the Cocoa Sand, a yellowish-gray, fine- to medium-grained, massive, fossiliferous sand; (3) the Pachuta Marl, a light greenish-gray, clayey, fossiliferous, calcareous sand or sandy limestone; and (4) the Shubuta, a light-gray to white, calcareous, fossiliferous, sandy clay. These divisions of the Yazoo can be traced in the subsurface for only a short distance downdip from their area of outcrop.

Fauna considered to characterize the Yazoo Clay, its middip equivalents, and the basal clastic part of the Ocala in the Florida panhandle include the Foraminifera *Bulimina jacksonensis* Cushman, *Robulus gutticostatus cocoaensis* (Cushman), and *Globigerina tripartita* Koch. Ostracoda that characterize these beds include *Cytheretta alexanderi* Howe and Chambers, *Clithocytheridea caldwellensis* (Howe and Chambers), *C. garretti* (Howe and Chambers), *Jugosocythereis bicarinata* (Swain), and *Haplocytheridea montgomeryensis* (Howe and Chambers). The latter species ranges downward into middle Eocene beds but does not occur above the top of the upper Eocene.

Barnwell Formation—The lower part of the Ocala Limestone grades laterally into more clastic rocks in northeastern Georgia. In the Savannah area, much of the lower part of the Ocala consists of light-brown, highly sandy, glauconitic, argillaceous limestone. This unit, unnamed at present, grades in turn to the north into the outcropping Barnwell Formation of eastern Georgia and southwestern South Carolina. The updip Barnwell consists of fine- to coarse-grained, gray, yellow, pink, and red arkosic sand and thin beds of light-gray to green, glauconitic, fossiliferous clay.

In parts of eastern Georgia, the Barnwell is divided into (1) a thin and locally occurring basal sand (possibly equivalent to the Clinchfield Sand), (2) a green to gray, sandy, locally glauconitic clay member (Twiggs Clay Member), and (3) an upper, massive, red, medium- to coarse-grained, locally clayey sand (Irwinton Sand Member). The Clinchfield sand and the members of the Barnwell Formation can be traced only a short distance downdip, where they grade into calcareous, argillaceous rocks that in turn grade seaward into the lower part of the Ocala Limestone.

Cooper Formation (lower members) and equivalent rocks—The upper part of the Ocala grades northward, by the addition of calcareous clay and the loss of large foraminifers, into a soft, white, argillaceous, sandy, slightly glauconitic, bryozoan-rich limestone that is the basal part of the Cooper Formation of South Carolina and northeastern Georgia. In South Carolina, the Cooper is divided into three members (Ward and others, 1979), the lower two of which are of late Eocene age. The uppermost member of the Cooper is of Oligocene age and is discussed in the Oligocene section of this report.

The basal Harleyville Member of the Cooper is a soft, clayey, micritic limestone that contains small amounts of glauconite and pyrite. A phosphate-pebble conglomerate is commonly found at the base of the Harleyville Member. The middle unit of the Cooper is the Parkers Ferry Member, a glauconitic clayey limestone that is highly fossiliferous. The Parkers Ferry Member represents the uppermost part of the late Eocene in South Carolina. The Cooper Formation is not subdivided in Georgia. Most of the Cooper in outcrop and in the shallow subsurface of Georgia is lithologically similar to the Parkers Ferry Member of South Carolina.

The updip equivalent of the Cooper Formation in Georgia is a medium- to coarse-grained, locally argillaceous and pebbly, massive red to reddish-brown sand. This unit, called the Tobacco Road Sand by Huddlestun and Hetrick (1978), is thought to be a marginal marine (lagoonal or estuarine) equivalent of the Cooper Formation. The Tobacco Road is of local importance only and is not recognizable in the subsurface.

Few cores or cuttings from wells that penetrated either the Barnwell Formation or the Cooper Formation and its equivalents were examined during this study. Although these strata are known to contain a sparse to well-developed microfauna in places, no species has been identified during this study as being characteristic of these formations.

Depositional environments—Practically all the rocks of late Eocene age in the study area were deposited in shallow, open to marginal marine environments. The Ocala Limestone was deposited in warm, shallow, clear water on a carbonate bank that was probably similar to the modern Bahama Banks. The basal part of the Ocala in western panhandle Florida and the Moodys Branch Formation, which is its updip equivalent, as well as the Yazoo Clay represent marginal marine (lagoon or estuary) to shallow, open-shelf conditions.

The Barnwell Formation and the Tobacco Road Sand were deposited in estuarine, sound, or lagoonal conditions. The Cooper Formation that lies downdip from these units represents shallow water, open marine conditions. The basal phosphate conglomerate of the Harleyville Member of the Cooper was deposited during transgression of the late Eocene sea.

OLIGOCENE SERIES

Rocks of Oligocene age are found over approximately two-thirds of the study area and occur in two separate large bodies. The more extensive area underlain by Oligocene rocks is a wide band that extends seaward from the outcrop of these rocks in Alabama, Georgia, and South Carolina. A second, somewhat smaller area of Oligocene strata covers the southwestern quarter of the Florida peninsula. Plate 10 shows the extent of these two main bodies of Oligocene rocks, the area where Oligocene strata crop out, and the configuration of the Oligocene surface. Throughout the study area, Oligocene rocks are in offlap relation to the upper Eocene and lie seaward of these older beds (compare pls. 8 and 10). Where Oligocene rocks are overlapped by Miocene sediments, the updip limit of the Oligocene is approximate because it is based on available well data; this approximate limit is shown as a dashed line on plate 10. The Oligocene Series consists of carbonate rocks throughout all of the study area except for southwestern Alabama, western panhandle Florida, and parts of northeastern Georgia and southwestern South Carolina, where clastic strata make up an important part of the Oligocene. The few scattered outliers of Oligocene lying between the two main bodies shown on plate 10, indicate that these rocks extended over a much wider area before being removed by erosion. Older rocks are exposed at scattered places within the widespread but generally thin body of the Oligocene in Georgia, where erosion has removed all of the Oligocene locally. The locations of most of the Oligocene outliers and the places where Oligocene rocks have been stripped are based on well data compiled for this study. A few of these features, however, are located from published sources, and thus lie in places where no well control is shown on plate 10. Erosional remnants to the north and west of the general updip limit of the Oligocene show that these rocks once extended over a much wider area.

Both large- and small-scale structural features affect the configuration of the Oligocene top. Large-scale features include (pl. 10) (1) the steep gulfward slope of the unit in southwestern Alabama, which reflects subsidence of the Gulf Coast geosyncline, (2) the low area in southern Gulf County, Fla., that represents the Southwest Georgia embayment, (3) the negative area in Glynn County, Ga., and adjacent counties that is the Southeast Georgia embayment, and (4) a low area in southwestern peninsular Florida that may represent a remnant of the South Florida basin. The northwest-southeast orientation of the axis of the South Florida basin is different from its alinement on the surface of older rock units (compare, for example, pls. 8 and 10). The high area shown on the Oligocene surface along the Gulf of Mexico parallel to the South Florida basin is not present on the upper Eocene top. This high probably acted as a sill or barrier during Oligocene time and partly restricted open circulation between the South Florida basin and the ocean. Smaller structural features shown on plate 10 include the northeast-trending series of small grabens in central Georgia that are collectively called the Gulf Trough and a coast-parallel normal fault that extends from Indian River County southeast through Martin County, Fla. The Oligocene has been eroded from the upthrown side of this fault but is preserved on its downthrown side.

The Oligocene top slopes generally seaward from a high of more than 300 ft above sea level in the unit's outcrop area in central Georgia to slightly more than 600 ft below sea level in both the Southwest and Southeast Georgia embayments. This general seaward slope is interrupted in northern Florida by a high area extending from Leon County eastward to Columbia County, where Oligocene rocks crop out. From a second outcrop area that extends southward from Citrus to Hillsborough Counties, Fla., Oligocene rocks slope into the South Florida basin, where the Oligocene top is more than 900 ft below sea level. The maximum measured depth to the top of the Oligocene is about 2,680 ft below sea level in well ALA-BAL-30 in southern Baldwin County, Ala. The maximum contoured depth is below 3,200 ft, to the southwest of this well. Although the top of the Oligocene is affected locally by erosion and karst topography, it is not as irregular as the top of upper Eocene strata.

The thickness of the Oligocene Series is shown on plate 11. Most of the contouring shown on this plate is based on well data. Where wells are scattered, the thickness of Oligocene rocks has been estimated by subtracting contours that represent the tops of upper Eocene and Oligocene rocks (pls. 8 and 10). Oligocene strata are generally less than 200 ft thick in the study area. Exceptions are southwestern Florida, where these rocks are more than 400 ft thick; southern Gulf and Franklin Counties, Fla., where they are more than 600 ft thick; and the southernmost part of Alabama, where they are more than 800 ft thick. These thick areas represent the South Florida basin, the Southwest Georgia embayment, and the northeastern rim of the Gulf Coast geosyncline, respectively. Throughout most of eastern Georgia and all of South Carolina, the thickness of the Oligocene Series only locally exceeds 100 ft and is generally 50 ft or less.

SUWANNEE LIMESTONE AND EQUIVALENT ROCKS

The name "Suwannee Limestone" was proposed by Cooke and Mansfield (1936, p. 71) for "yellowish limestone typically exposed along the Suwannee River in Florida, from Ellaville...almost to White Springs...." They considered these beds to be of Oligocene (Vicksburgian) age rather than Miocene as previous investigators had postulated. Cores and well cuttings examined during this study show that the Suwannee usually consists of two rock types: (1) cream to tan, crystalline, highly vuggy limestone containing prominent gastropod and pelecypod casts and molds and (2) white to cream, finely pelletal limestone containing small foraminifers and pellets of micrite bound by a micritic to finely crystalline limestone matrix. Although these two rock types are complexly interbedded in places, the pelecypod cast-and-mold limestone is more characteristic of the upper part of the Suwannee and is the lithology most representative of the entire formation in most of Georgia and eastern panhandle Florida. The micritic pelletal limestone that is characteristic of the lower part of the Suwannee is locally found higher in the formation in southwestern Florida. Because the Suwannee, like the Ocala, cannot be divided everywhere, the two facies have not been delineated in this report.

The upper part of the Suwannee has been locally silicified, and this chert-rich horizon was named the Flint River Formation in Georgia. These silicified beds are rarely found in the subsurface and appear to merely represent local diagenetic conditions rather than a widespread mappable variation within the Suwannee. The term Flint River is accordingly not considered to be a valid formational name in this report.

The upper part of the Suwannee in the Georgia subsurface commonly consists of medium to coarsely crystalline, light-brown to honey-colored, saccharoidal, vuggy dolomite. The erosional remnants of Suwannee preserved as outliers several miles distant from the main bodies of Oligocene rocks (pl. 10) and consisting of either limestone or dolomite show that marine Oligocene strata once covered the entire study area. Locally, the cast-and-mold facies of the Suwannee contains fine-grained sand. Very locally, the micritic pelletal facies contains trace amounts of fine- to medium-grained, light- to dark-brown phosphate. In outcrop, the Suwannee locally weathers to a nodular, rubbly surface owing to the removal of layers, lenses, and stringers of soft argillaceous limestone.

The Suwannee grades northward in northeastern Georgia and South Carolina into part of the Cooper Formation by the addition of clay and sand and the loss of limestone. Westward, across panhandle Florida and southern Alabama, the Suwannee appears to grade into the lower part of the Bucatunna Formation. In that area, the Suwannee consists of tan limestone, dolomitic limestone, and light-colored calcareous clay. Some of these beds were called "Byram" or "Glendon" by early workers (Cooke and Mossum, 1929; Cooke, 1945) primarily on the basis of their stratigraphic position. Some faunal aspects of the Suwannee in Florida are Chickasawhayan (late Oligocene); others are Vicksburgian (early Oligocene). The unit is thus interpreted in this report as spanning both ages (pl. 2). The Suwannee in Georgia is thought to be late Oligocene (Huddlestun, 1981).

Microfauna considered characteristic of the Suwannee include the larger Foraminifera *Lepidocyclina leonensis* Cole and *L. parvula* Cole as well as the small Foraminifera *Pararotalia byramensis* Cushman and *P. mexicana mecatepecensis* Nutall, which are closely related. Although the genus *Miogypsina* ranges into younger strata in the central Gulf Coast, it does not occur above the top of the Suwannee in the study area. The larger Foraminifera *Discorinopsis gunteri* Cole, *Dictyoconus cookei* (Moberg), and *Coscinolina floridana* Cole are commonly found in the Suwannee, but these three species are also found lower in the section in the middle Eocene Avon Park Formation. Some authors think that these species have been reworked from the Avon Park into the Suwannee. Others think that they are merely long-ranging species that are "facies seekers." That is, their reappearance in the Suwannee means nothing more than the reestablishment of environmental conditions like those in which the Avon Park was deposited. Most individuals of these three species from the Suwannee examined during this study appeared fresh and unaltered, and the species are widespread throughout the cast-and-mold facies of the formation. In addition, there is no apparent Avon Park source from which these fossils could have been reworked. The isolated patches of Avon Park that are exposed through a cover of upper Eocene sediments (pl. 8) are too small and too scattered to provide a source from which these widely distributed Foraminifera could have been reworked into the Suwannee. This author therefore believes that these are long-ranging species indigenous to the Suwannee Limestone.

Bumpnose, Red Bluff, and Forest Hill Formations

In panhandle Florida, the Oligocene Series thickens considerably (pl. 11) and becomes increasingly clastic westward. In addition, some carbonate units that are older than the Suwannee are present at the base of the Oligocene (pl. 2). One such unit is the Bumpnose Formation, a name applied by Moore (1955) to a soft, white, somewhat glauconitic, highly fossiliferous (pelecypod and gastropod casts and molds and bryozoan and foraminiferal remains) limestone that crops out in central Jackson County, Fla. Moore thought that the Bumpnose represented the uppermost part of the late Eocene but recognized that many of its faunal elements were Oligocene. Subsequent work by Hazel and others (1980) confirmed the findings of MacNeil (1944) and Cooke (quoted by Moore, 1955, p. 38) that the beds that Moore called Bumpnose correlate with the Red Bluff Formation of Alabama of known Oligocene age. The Bumpnose in its type area is very likely a transitional unit between the late Eocene and early Oligocene. The Bumpnose Formation, however, is placed in the Oligocene in this report because carbonate rocks in western Alabama that are in the same stratigraphic position as the Bumpnose and that can be shown to correlate with it are of Oligocene age (Hazel and others, 1980).

The Bumpnose grades northwestward into the Red Bluff Formation, which is mostly dark-gray to brown, fossiliferous, glauconitic clay that contains some iron-rich beds and siderite concretions, and local beds of glauconitic, sandy, fossiliferous limestone. The Red Bluff in turn grades westward into the Forest Hill Formation, a dark-colored silt, sand, and clay sequence that is highly lignitic near its top and base. Gulfward, the Bumpnose merges with the basal part of a thick sequence, unnamed at present, of interbedded pelletal limestone, micritic limestone, and tan, finely crystalline dolomite. To the southwest across the Florida panhandle, the Bumpnose pinches out in western Bay County, Fla. The Red Bluff and Forest Hill Formations are recognizable in the subsurface only a short distance downdip of their outcrop.

Mint Spring and Marianna Formations

The Marianna Formation is a soft, cream to white, highly fossiliferous (mostly large foraminifers), glauconitic limestone that is argillaceous in places. The amount of clay in the Marianna increases northwestward across southern Alabama as the Marianna grades into the Mint Spring Formation, a thin, fossiliferous, glauconitic sand or clayey sand that represents the base of the Vicksburg Group in western Alabama (Hazel and others, 1980). Gulfward from its type area in central Jackson County, Fla., the Marianna becomes part of a thick unnamed sequence of Oligocene limestone and dolomite beds. Like the Bumpnose, the Marianna pinches out to the southwest in western Bay County, Fla. The Mint Spring is not recognizable in the subsurface.

Glendon Formation

The Glendon Formation is a thin, fossiliferous, cream-colored limestone that occurs in the updip Oligocene of western Alabama. The Glendon is not recognizable in the subsurface in downdip areas of southern Alabama and panhandle Florida and is not thought to crop out in Florida. The micritic, pelletal, lower part of the outcropping Suwannee Limestone at its type locality was once thought to be equivalent to either the Glendon (Cooke and Mossum, 1929) or the Byram (Cooke, 1945). This report considers these beds to be part of the Suwannee.

Byram Formation

The Byram Formation in its outcrop area in western Alabama consists of light-colored, sandy, glauconitic, calcareous clay and some beds of sandy, white, fossiliferous limestone. The Byram is thin in outcrop and appears to merge with the Bucatunna Formation in the shallow subsurface by loss of limestone and increase of clay. In some publications, the terms Glendon and Byram appear to have been used somewhat interchangeably.

Bucatunna Formation

To the west of eastern Walton County and western Bay County, Fla., the basal unit of the subsurface Oligocene is a massive, light- to medium-gray, calcareous, fossiliferous clay containing trace amounts of fine sand. This unit, called the Bucatunna Formation, has a distinctive low-resistivity electric log pattern and constitutes one of the most easily recognizable stratigraphic markers in westernmost Florida and southern Alabama. Updip, the Bucatunna is less marine and consists of dark-colored carbonaceous silt, bentonitic clay and thin interbeds of yellow sand. The Bucatunna forms an excellent confining bed, separating permeable limestones of late Eocene age (Ocala) from late Oligocene limestone strata that are also highly permeable. The Bucatunna merges updip with more sandy or calcareous Oligocene beds and passes by facies change eastward into an unnamed thick sequence of limestone and dolomite beds of Oligocene age in eastern panhandle Florida.

Chickasawhay Formation

The uppermost part of the Oligocene Series in southern Alabama and much of panhandle Florida consists of white, micritic to pelletal, hard to semi-indurated, fossiliferous limestone and thin to thick beds of light- to dark-brown, fine to medium crystalline, vuggy dolomite. This unit is thought to be equivalent to the outcropping Chickasawhay Formation of western Alabama. The Chickasawhay in outcrop consists of bluish-gray, soft, glauconitic, calcareous clay and some beds of white fossiliferous limestone. The Chickasawhay can be distinguished in the subsurface as far east as central Bay County, Fla., where it grades into unnamed interbedded Oligocene limestone and dolomite that in turn thin and grade northward and eastward into the upper part of the Suwannee Limestone.

The Paynes Hammock Formation, a thin, calcareous, fossiliferous sand and clay sequence that overlies the Chickasawhay, cannot be distinguished from the Chickasawhay in the subsurface, and the two are thus not separated in this report.

In most of the subsurface of the western third of the study area, Oligocene strata can be divided into the basal Bucatunna Formation and the upper Chickasawhay Formation. Fauna considered to characterize these two units include the Foraminifera *Pulvinulina mariannensis* Cushman, *Robulus vicksburgensis* (Cushman) Ellisor, *Palmula caelata* (Cushman) Israelsky, and *Globigerina selli* (Borsetti). The ostracode *Aurila kniffeni* (Howe and Law) is also considered characteristic of these strata.

COOPER FORMATION (ASHLEY MEMBER)

The uppermost part of the Cooper Formation, called the Ashley Member by Ward and others (1979), is of Oligocene age, in contrast to the late Eocene age of the lower two members of the Cooper. The Ashley Member consists of brown to tan, soft, calcareous, clayey sand that usually contains much phosphate and glauconite and carries a rich microfauna. The thickness of the member is highly variable. To the south and southeast, the Ashley Member grades into the Suwannee Limestone by the addition of impure limestone beds and the loss of clastic strata. The microfauna of the Cooper were not examined in enough detail during this study to determine which species are characteristic of any of the formation's members, including the Ashley. However, the foraminifer *Pararotalia mexicana mecatepcensis* Nutall was identified from the upper part of the Cooper in several wells in northeastern Georgia.

CHANDLER BRIDGE FORMATION

The Chandler Bridge Formation (Sanders and others, 1982) is a thin sequence of clayey phosphatic sand beds that unconformably overlies the Ashley Member of the Cooper Formation. Chandler Bridge beds occur locally and appear to be preserved only in low areas on the Ashley surface. The Chandler Bridge contains no microfauna and is dated Oligocene on the basis of its stratigraphic position and the primitive aspect of its cetacean fauna, which somewhat resembles forms found in the upper Oligocene of Europe.

DEPOSITIONAL ENVIRONMENTS

The Suwannee Limestone and the equivalent thick sequence of unnamed interbedded limestone and dolomite in eastern panhandle Florida were deposited in a carbonate bank environment. The part of the Cooper Formation that is of Oligocene age (Ashley Member) and the Chandler Bridge Formation that overlies it were laid down in a marginal marine environment. All of the Oligocene units in Alabama and those in updip areas of panhandle Florida were deposited in shallow marine to restricted marine (lagoonal or estuarine) environments. The formations that are mostly limestones (Bumpnose, Marianna, and Glendon) formed in shallow, warm, open marine waters. Those units that are highly argillaceous and glauconitic (Red Bluff, Mint Spring, Byram, and Chickasawhay) are estuarine to lagoonal for the most part but may grade into shallow shelf, open marine deposits downdip. The dark-colored clays that are part of the Forest Hill and the updip portion of the Bucatunna are mostly lagoonal but in places may represent deltaic conditions. The Bucatunna and Forest Hill represent local regressive phases of the generally transgressive Oligocene sea.

MIOCENE SERIES

Rocks of Miocene age underlie most of the study area except for a wide band in northwestern peninsular Florida, where they have largely been removed by erosion. These strata are mostly clastic, with the exception of (1) sandy limestone that comprises the Tampa Formation and its equivalents and (2) dolomite beds that commonly make up the lower part of the Hawthorn Formation. Miocene rocks crop out over more of the study area than any other Tertiary unit and are highly dissected in outcrop and shallow subcrop locales. The paleogeography of the eastern Gulf Coast was very different in Miocene time than it had been before. The carbonate bank environment that characterized peninsular Florida and adjacent areas during most of Tertiary time was covered during the Miocene by an influx of clastic sediments. Chemical conditions in parts of the Miocene ocean were also quite different and resulted in the widespread deposition of phosphatic and siliceous sediments, especially during middle Miocene time.

The extent and the configuration of the surface of the Miocene Series is shown on plate 12, along with the area where these rocks crop out. Over more than half of their extent, Miocene rocks are at or above sea level. The contour interval used on plate 12 is smaller than that used on maps of the structural surfaces of older units to better portray the irregular topography developed on the top of the Miocene. The rough surface of the unit and the numerous small outliers preserved as erosional remnants apart from the main body of Miocene rocks show that the Miocene surface has been deeply eroded. At a few scattered places within the main body of Miocene rocks, older units are exposed where the Miocene has locally been completely eroded through.

In outcrop areas in Alabama and Georgia, Miocene rocks are found at altitudes of more than 300 ft above sea level. In south-central peninsular Florida, the Miocene top locally is at an altitude of more than 150 ft above sea level. The maximum measured depth to the top of the Miocene is about 1,360 ft below sea level in well ALA-BAL-30 in southern Baldwin County, Ala., and the maximum contoured depth of the unit is below 1,700 ft to the southwest of this well. Over much of south Florida, the Miocene top is 100 to 200 ft below sea level. Locally, along small faults in extreme southeastern Florida, the top of the unit has been dropped as much as 250 ft on the downthrown side of the faults. The only major structural features shown on plate 12 are a negative area in the southwestern tip of Florida that represents a part of the South Florida basin, and a steep gulfward slope of the Miocene top in southern Alabama produced by subsidence of the Gulf Coast geosyncline.

The thickness of the Miocene Series is shown on plate 13, as are those areas where the Tampa Limestone and its equivalents comprise part of the Miocene. The contours on this map are based primarily on well data. Certain features shown on this map, such as the small fault extending from Martin County to St. Lucie County in southeastern Florida, are taken from published sources. In areas of sparse control, the well-point data have been supplemented by subtracting contoured surfaces of the Miocene and Oligocene. Where Oligocene rocks are absent, the difference in altitude between the Miocene and late Eocene tops was used as a thickness approximation. Miocene strata thicken from a featheredge where they crop out to a thickness of more than 800 ft in southern Florida, more than 500 ft in southeastern Georgia, and more than 1,400 ft in southern Alabama. In a wide area across north-central peninsular Florida, Miocene rocks are very thin on the Atlantic side and absent to patchy on the Gulf side. This area of thinning generally coincides with an area where Oligocene rocks have been stripped (pl. 10) and where upper Eocene rocks are thin (pl. 9). The many local variations in the thickness of the Miocene shown on plate 13 are due to extensive erosion of the unit.

Although the Miocene rocks of the Southeastern United States have been studied in detail for many years, they remain poorly understood. This lack of understanding is due in part to the complexity of facies change within the rocks. For example, in western Florida, detailed work on somewhat scattered exposures of highly variable, shallow marine Miocene beds has resulted in a proliferation of "formations" whose extent and exact stratigraphic relations are poorly defined. Certain economic aspects of the Miocene, such as phosphorites and high-magnesium clays, have been closely scrutinized, but an economic study is likely to be of either local range or narrow focus. It is beyond the scope of this study to address the many problems of Miocene stratigraphy; therefore, the stratigraphic breakdown of the Miocene used herein is a general one (pl. 2). Greater detail on Miocene stratigraphy and various Miocene problems is presented in a collection of papers edited by Scott and Upchurch (1982).

The entire Miocene Series was mapped together as a single unit during this study. Microfauna that are considered characteristic of the undifferentiated Miocene in the study area include the Foraminifera *Amphistegina chipolensis* Cushman and Ponton, *A. lessoni* d'Orbigny, *Bolivina floridana* Cushman, *B. marginata multicostata* Cushman, *Elphidium chipolensis* (Cushman), and *Sorites sp.* Ostracoda considered characteristic of the Miocene include *Aurila conradi* (Howe and McGuirt) and *Hemicythere amygdula* Stephenson.

Tampa Limestone

The basal part of the Miocene Series in part of west-central peninsular Florida and much of the central and eastern parts of the Florida panhandle consists of the Tampa Limestone. As it is used in this report, the Tampa is a white to light-gray, sandy, hard to soft, locally clayey, fossiliferous (pelecypod and gastropod casts and molds) limestone that contains phosphate and chert in places. The phosphate content of the Tampa is low, however, in comparion with that of the overlying Hawthorn Formation. The mollusk remains in the Tampa vary from trace amounts up to 90 percent of the rock. Except for the sand and phosphate that it contains, the Tampa closely resembles the Suwannee Limestone. Some confusion exists in the literature as to the distinction between these formations, owing in part to the fact the Tampa-Suwannee contact is gradational in the type area of the Tampa (King and Wright, 1979). A difference of opinion also exists concerning the age of the Tampa. Certain mollusks from the unit are also found in the Paynes Hammock Formation of eastern Mississippi, once thought to be of early Miocene age but now known to be part of the Oligocene (Poag, 1972). Foraminifera from the Tampa, however, indicate that the formation is of early Miocene age, and the formation is placed in the early Miocene in this report.

From its type area in and around Tampa Bay, the Tampa Limestone grades southward into white, hard to semi-indurated, finely crystalline to micritic limestone that contains traces of sand, phosphate and scattered pelecypod casts and molds at irregular intervals. The basal part of this fine-textured limestone sequence consists largely of finely pelletal, micritic limestone. To the east and south, all these limestones become silty, clayey, and dolomitic and appear to grade into the lower part of the Hawthorn Formation.

The light-gray, sandy, pelecypod- and gastropod-rich lower Miocene limestone in the eastern and central parts of the Florida panhandle has been called the Tampa Limestone by some workers and the St. Marks Formation by others. This author could not distinguish between the Tampa and the St. Marks either in outcrop or in well cuttings, and all fossiliferous lower Miocene limestones in the study area are therefore called Tampa Limestone in this report. The Tampa in the Florida panhandle appears to pinch out against the Hawthorn Formation where it is overlapped by the latter unit. Marsh (1966) recognized that some limestones in the southern parts of Escambia and Santa Rosa Counties in extreme western Florida contain an early Miocene fauna, but he was unable to separate these strata from underlying limestone beds of the Chickasawhay Formation (Oligocene). This author agrees that a thin sequence of limestone is present near the Gulf Coast in these counties but, like Marsh, cannot consistently differentiate the Oligocene and early Miocene there. The thin carbonate sequence is thus mapped as part of the Oligocene in this report.

The Tampa Formation does not extend into Georgia. The beds that Counts and Donsky (1963) and Herrick and Vorhis (1963) called Tampa are in reality part of the basal Hawthorn, which consists largely of dolomite and dolomitic limestone.

The Catahoula Sandstone, a yellowish-gray sand and sandy clay unit that occurs locally in outcrop and in the shallow subsurface in Alabama, is thought to be a lower Miocene unit and therefore time equivalent to the Tampa. The two formations, however, are not connected. The Catahoula appears to grade into the lower part of the Hawthorn Formation. The Edisto Formation of South Carolina, a yellow-brown, sandy, fossiliferous limestone that occurs as erosional remnants on the top of the Cooper Formation, is also of early Miocene age but, like the Catahoula, is not connected to the Tampa Limestone.

Microfauna identified from the Tampa during this study include the Foraminifera *Amphistegina chipolensis* Cushman and Ponton, *Elphidium chipolensis* (Cushman), and *Sorites* sp. These species are not restricted to the Tampa, however, and are commonly found also in younger Miocene units.

Hawthorn Formation

The Hawthorn Formation is the most widespread and the thickest Miocene unit in the Southeastern United States. East of longitude 85° W, the Hawthorn constitutes most of the entire thickness of the Miocene strata shown on plate 13. The Hawthorn is a complexly interbedded, highly variable sequence that consists mostly of clay, silt, and sand beds, all of which contain scarce to abundant phosphate. Phosphatic dolomite or dolomitic limestone beds are common in the lower part of the formation. The argillaceous beds of the Hawthorn are usually green but locally are cream or gray. Hawthorn sands are light to dark brown where they are highly phosphatic and light green to gray where they carry only trace amounts of phosphate. The dolomite and limestone beds of the Hawthorn are most commonly brown but locally are cream to white. Most of the phosphate that occurs throughout the Hawthorn is fine to medium sand sized, but beds of pebble-sized phosphate are by no means rare, especially in the upper third of the formation.

Locally, the Hawthorn can be roughly divided (Carr and Alverson, 1959; Miller and others, 1978; Scott and Upchurch, 1982). Although the number of zones and their exact lithology vary greatly from place to place, the Hawthorn generally consists of a basal calcareous unit, a middle clastic unit, and an upper unit that is a highly variable mixture of clastic and carbonate rocks. The middle and upper parts of the Hawthorn everywhere contain more phosphate than the lower calcareous unit. Hawthorn phosphorites are mined over a large area in central Florida and are locally exploited in Hamilton County in northern Florida. Although there is some disagreement about the exact environment of deposition and mechanism of concentration of the phosphate minerals in the Hawthorn, the consensus is that the phosphate was deposited from upwelling, cold marine waters (Riggs, 1979; Miller, 1982a).

There is much local variation of rock types within the Hawthorn. Some Hawthorn clay beds contain abundant diatom remains (Miller, 1978). Palygorskite (attapulgite), a magnesium-rich clay that is useful because of its absorptive properties, is mined from the upper part of the Hawthorn in Gadsden County, Fla., and Decatur County, Ga. (Weaver and Beck, 1977). In southwestern Florida, there are thick sequences of light-gray silty to argillaceous limestone in the upper and lower thirds of the formation. In Seminole and Orange Counties, Fla., the Hawthorn is very thin and consists of beds of shell material bound together by light-gray calcareous clay. Southeast of Tampa, Fla., the uppermost part of the Hawthorn consists of brown, orange, and red clayey, slightly phosphatic sand. In northeastern Georgia, Hawthorn beds consist mostly of green silt and clay and interbedded white limestone and fine- to coarse-grained sand.

Because of its heterogeneity and the predominantly fine textured nature of both the clastic and the carbonate beds within the Hawthorn, the entire formation constitutes a low-permeability rock sequence. Where it is present, the Hawthorn Formation comprises most of the upper confining unit of the Floridan aquifer system.

The Hawthorn Formation is considered by most workers to be of middle Miocene age, and it is so regarded in this report. However, fauna are sparse within the Hawthorn, and the exact relations between this formation and the complex Miocene section of panhandle Florida are unclear at present. Parts of the Hawthorn may be as old as early Miocene or as young as late Miocene. Most of the unit, however, appears to be of middle Miocene age.

Alum Bluff Group

West of longitude 85° W, or approximately at the Apalachicola River in eastern panhandle Florida, the Hawthorn Formation passes by facies change into the lower part of a thinly bedded, complex, finely to coarsely clastic, often highly shelly sequence of strata called the Alum Bluff Group (pl. 2). Several formations have been identified within this group, chiefly on the basis of work done in outcrop areas and in the shallow subsurface. For the most part, these formations are thin and of limited areal extent, and are in many cases not well defined. More detail on the Miocene of panhandle Florida is presented in reports by Puri (1953a), Puri and Vernon (1964) and in a collection of papers edited by Scott and Upchurch (1982).

The Alum Bluff Group as used in this report refers to a sequence of gray to green clay and medium- to coarse-grained sand beds that locally contain much carbonized plant material or mollusk shells. Beds of middle and late Miocene age have been reported from the Alum Bluff Group, but no age separation within the group has been made in this study. Alum Bluff beds grade westward into coarse gravelly sands and thin clay interbeds in westernmost Florida and southwestern Alabama. Alum Bluff Group equivalents in southern Alabama are an undifferentiated sequence of gray clays and fine- to medium-grained sands. Local, patchy erosional remnants of upper Miocene beds that occur at scattered places in parts of peninsular Florida are equivalent to the upper part of the Alum Bluff Group but are undifferentiated in this report.

Depositional environments

The mollusk-rich, cast-and-mold limestone of the Tampa represents a remnant of the carbonate bank environment that characterized the Florida peninsula throughout most of Tertiary time. The Tampa was deposited in warm, shallow, clear, open marine waters in a basin that received little or no clastic supply.

The Hawthorn Formation was deposited under conditions quite different from those that existed in the early Miocene. Hawthorn sediments were laid down in shallow to moderately deep (inner to middle shelf) marine waters in a basin that received copious amounts of clastic material. The highly phosphatic and siliceous (diatom rich) beds of the Hawthorn, as well as some of the microfauna recovered from the formation, show that the waters in the Hawthorn sea were colder than those in which older Cenozoic units were deposited. The considerable local relief on the Hawthorn sea floor (Miller, 1982a) was a factor in the deposition and concentration of some of the Hawthorn phosphorites.

The Alum Bluff Group was deposited in shallow, warm to temperate waters, mostly in a marginal marine environment. Some of the gravelly sands that are part of the Alum Bluff Group in westernmost Florida may be of fluvial origin.

TERTIARY AND QUATERNARY SYSTEM: POST-MIOCENE ROCKS

GENERAL

All beds in the study area that are younger than Miocene are grouped together in this report and mapped as a single unit. Post-Miocene strata can generally be divided into a basal sequence of marginal to shallow marine beds overlain by a series of sandy marine terrace deposits that are in turn capped by a thin layer of fluvial sand and (or) residuum. The basal beds having a marine aspect are mostly of Pliocene age, the terrace deposits were laid down during the Pleistocene, and the fluvial and residual materials are of Holocene age (pl. 2). There are two major exceptions to this general post-Miocene sequence. In southern Florida, practically all post-Miocene strata are of shallow or marginal marine origin and comprise a complex and highly variable sequence of thin formations whose relations are best known along the southeastern coast. In southwestern Alabama and the westernmost part of the Florida panhandle, post-Miocene rocks are mostly a thick sequence of coarse-grained, fluvial, gravelly sands that locally contain interbedded clays, mostly near the base of the sand sequence.

The top of post-Miocene rocks has not been mapped because the surface of the unit obviously is the same as the present-day topographic surface in the study area, and the configuration of this surface is available from other published sources. The general thickness of post-Miocene rocks is shown on plate 14. This map has been contoured on the basis of well data alone, in contrast with the thickness maps of the older units discussed in this report. The purpose of plate 14 is to show the locations of the larger thickness variations in the post-Miocene unit rather than detailed changes. Over most of the study area, post-Miocene sediments are less than 100 ft thick and in many places form a surface veneer that is only 10 to 50 ft thick. In southwestern Alabama, thick Pliocene fluvial deposits make up most of the 1,400-ft-thick sequence of post-Miocene rocks found there.

PLIOCENE SERIES

Pliocene deposits in western panhandle Florida and in southwestern Alabama are assigned in this report to the Citronelle Formation. The Citronelle is a thick, mostly fluvial unit that consists mainly of medium to coarse sand containing many stringers of gravel and a few thin clay beds. There is much iron oxide in the formation, along with minor amounts of organic material. It is possible that the upper part of the Citronelle is Pleistocene in age (Marsh, 1966) but the entire formation is placed in the Pliocene in this report. The Citronelle thins to the north and east, and, if it is present outside southwestern Alabama and western Florida, it cannot be distinguished from younger terrace deposits.

Pliocene rocks in much of central Florida are represented by the Bone Valley Formation, a highly phosphatic sequence of sand and clay beds that locally contains a vertebrate fauna of Pliocene age. The extent and thickness of the Bone Valley are uncertain because the unit is difficult to distinguish from the underlying Hawthorn Formation in places. In southeastern Florida, the Tamiami Formation, a white to cream limestone that contains much sand in pockets and as admixed material, is of Pliocene age. The Tamiami and the Bone Valley are not connected. The Caloosahatchee Formation overlies the Tamiami in southern Florida. In scattered places in central and northern peninsular Florida, thin patches of shallow marine rocks are probably Caloosahatchee equivalents. The Caloosahatchee and its equivalents consist of a thin sequence of interbedded clay, calcareous clay, and sand that locally contains much broken shelly material. The upper part of the Caloosahatchee is of Pleistocene age (pl. 2).

The Raysor Formation of southwestern South Carolina is a bluish-gray, shelly, calcareous sand unit of Pliocene age that extends into northeastern Georgia. Beds now called Raysor were formerly included in the Duplin Formation of northeastern South Carolina, but Blackwelder and Ward (1979) showed that the Raysor is a separate unit. The Goose Creek Limestone (Weems and others, 1982) is a sandy, phosphatic, shelly limestone of Pliocene age that is found locally in South Carolina. The relation between the Goose Creek and the Raysor is not known at present (1984) since the two units have not been found in contact. In southeastern Georgia, the Charlton Formation, a dark brownish-green, soft, fossiliferous, locally micaceous to phosphatic clay, represents the Pliocene Series.

PLEISTOCENE SERIES

Over most of the study area, Pleistocene rocks consist of medium- to coarse-grained, tan, white, and brown sand that locally contains trace amounts of carbonaceous material and broken shell fragments. These sands underlie a series of poorly defined to well-defined terraces that are thought to have formed during the Pleistocene Epoch as seas rose and fell in response to glacial and interglacial episodes (MacNeil, 1950). There is little agreement on the number of these terraces, however, and it is possible that some of the higher ones represent pre-Pleistocene deposits (Healy, 1975). In this report, all the terrace materials are considered to be Pleistocene.

In southwestern South Carolina and northeastern Georgia, the sandy terrace deposits are locally underlain by red and yellow sands that contain thin beds of shell and stringers of phosphate. These strata are equivalent to the Waccamaw Formation of northeastern South Carolina. In southeastern Florida, Pleistocene strata consist of a series of thin and variable marine to marginal marine deposits whose relations are complex. Several highly permeable clastic and carbonate Pleistocene units, taken together, comprise most of the Biscayne aquifer, an important source of water in southeastern Florida. For purposes of this report, separate Pleistocene formations are not delineated in southern Florida. Detailed studies on the Pleistocene of southern Florida include reports by Parker and Cooke (1944), DuBar (1958), and Puri and Vernon (1964).

HOLOCENE SERIES

Holocene deposits in the study area include thin sand and gravel deposits that are mostly adjacent to present-day streams and dune, estuarine, and lagoonal sediments contiguous to the modern coast. Residuum developed from the weathering of older sediments and local windblown materials are also included in the Holocene. Holocene strata are not mapped separately in this report, nor are the different Holocene depositional environments delineated.

DEPOSITIONAL ENVIRONMENTS

Pliocene rocks in southeastern Florida (Tamiami and Caloosahatchee Formations) were deposited in shallow to marginal marine environments. The Bone Valley Formation of central Florida is mostly of fluvial origin and is comprised largely of material reworked from underlying Miocene rocks (Puri and Vernon, 1964). The Citronelle Formation of southern Alabama and westernmost Florida represents a thick sequence of fluvial beds. The Raysor and Charlton Formations of South Carolina and easternmost Georgia were deposited in lagoonal to estuarine conditions. The Goose Creek Limestone was laid down in a shallow marine (inner shelf) environment.

Pleistocene rocks throughout most of the study area represent a series of constructional sandy marine terraces deposited at the shoreline of a fluctuating Pleistocene sea. The Waccamaw Formation equivalents in South Carolina and the complex series of Pleistocene units in southeastern Florida represent marginal marine depositional conditions. All Holocene materials in the study area are either of fluvial origin or derived from the weathering of older rocks.

AQUIFERS AND CONFINING UNITS

GENERAL

The ground-water system beneath the study area generally consists of two major water-bearing units; a surficial aquifer and the Floridan aquifer system. In most places, a low-permeability sequence of rocks herein called the upper confining unit of the Floridan aquifer system separates the Floridan from the surficial aquifer. The Floridan is everywhere underlain by low-permeability rocks that are called the lower confining unit of the Floridan aquifer system in this report.

The surficial aquifer consists mostly of poorly consolidated to unconsolidated clastic rocks (except for southeastern Florida, where it is composed of limestone). Most of the water within the surficial aquifer occurs under unconfined conditions. The Floridan aquifer system's upper confining unit, which lies between the Floridan and the surficial aquifer in many places, consists mostly of low-permeability clastic rocks.

The Floridan aquifer system is a more or less vertically continuous sequence of generally highly permeable carbonate rocks whose degree of vertical hydraulic connection depends largely on the texture and mineralogy of the rocks that comprise the system. The high permeability is only rarely vertically continuous. Flowmeter data from scattered wells show that the aquifer system usually consists of several very highly permeable zones, which generally conform to bedding planes and which commonly are either solution riddled or fractured. These zones, which contribute most of the water to wells, are separated by rocks whose permeability ranges from only slightly less to considerably less than that of the high-yield zones. Because the aquifer system (and its upper and lower confining beds) is defined primarily on the basis of permeability, both the top and the base of the system as mapped in this report are composite surfaces that locally cross formation and age boundaries. Accordingly, the time- and rock-stratigraphic units that make up the aquifer system and its contiguous confining beds vary widely from place to place.

Over much of southern Florida, the aquifer system consists of several relatively thin, highly permeable zones isolated from one another by relatively thick sequences of low-permeability rocks. Differences in the hydraulic heads the several highly permeable zones and differences in the quality of the water that they contain show that the zones behave essentially as separate aquifers.

The Floridan aquifer system's lower confining unit consists of either low-permeability clastic rocks or evaporite deposits. The Floridan is everywhere underlain by these relatively impermeable strata, which separate the high-permeability carbonate rocks from older, deeper aquifers that are mostly of Cretaceous age.

SURFICIAL AQUIFER

A surficial aquifer containing water under mostly unconfined or water-table conditions is present throughout all of the study area except for those places where the Floridan aquifer system or its overlying confining bed is exposed at land surface. The surficial aquifer consists predominantly of sand, but gravel, sandy limestone, and limestone are important constituents in places. Where surficial deposits are thick, highly permeable, and extensively used as sources of ground water, they have been given aquifer names, such as the Biscayne aquifer in southeastern Florida and the sand-and-gravel aquifer in westernmost panhandle Florida. Figure 6 shows the extent of the Biscayne and sand-and-gravel aquifers, which grade laterally into widespread but thin sands that are called simply a surficial aquifer.

The term surficial aquifer as used in this report refers to any permeable material (other than that which is part of the Floridan aquifer system) that is exposed at land surface and that contains water under mostly unconfined conditions. The surficial aquifer may be in direct hydraulic contact with the Floridan or be separated from it by confining beds. Rainfall easily infiltrates the permeable surficial materials and, after percolating downward to the water table, moves either laterally to points where it is discharged into surface streams or vertically downward to recharge either the Floridan or local intermediate aquifers, if the water levels in these deeper aquifers are lower than those in the surficial aquifer. Such downward leakance may be rapid or slow, depending on the presence and character of intervening confining beds (low-permeability rocks) and the head differences between the surficial aquifer and deeper aquifers. Water levels within the surficial aquifer fluctuate widely and rapidly in response to rainfall and other natural stresses such as evapotranspiration or the stages of streams. The general configuration of the water-level surface (water table) of the surficial aquifer is a subdued replica of the configuration of land surface.

The surficial aquifer is important in simulating ground-water flow in the Floridan aquifer system because it serves as a "source-sink" bed for the Floridan. Where the head at the base of the surficial aquifer is higher than the potentiometric surface of the underlying Floridan, the surficial aquifer is the "source" of water that moves downward to recharge the Floridan. Where the potentiometric surface of the Floridan is higher than the head at the base of the surficial aquifer, flow is upward from the Floridan to the surficial

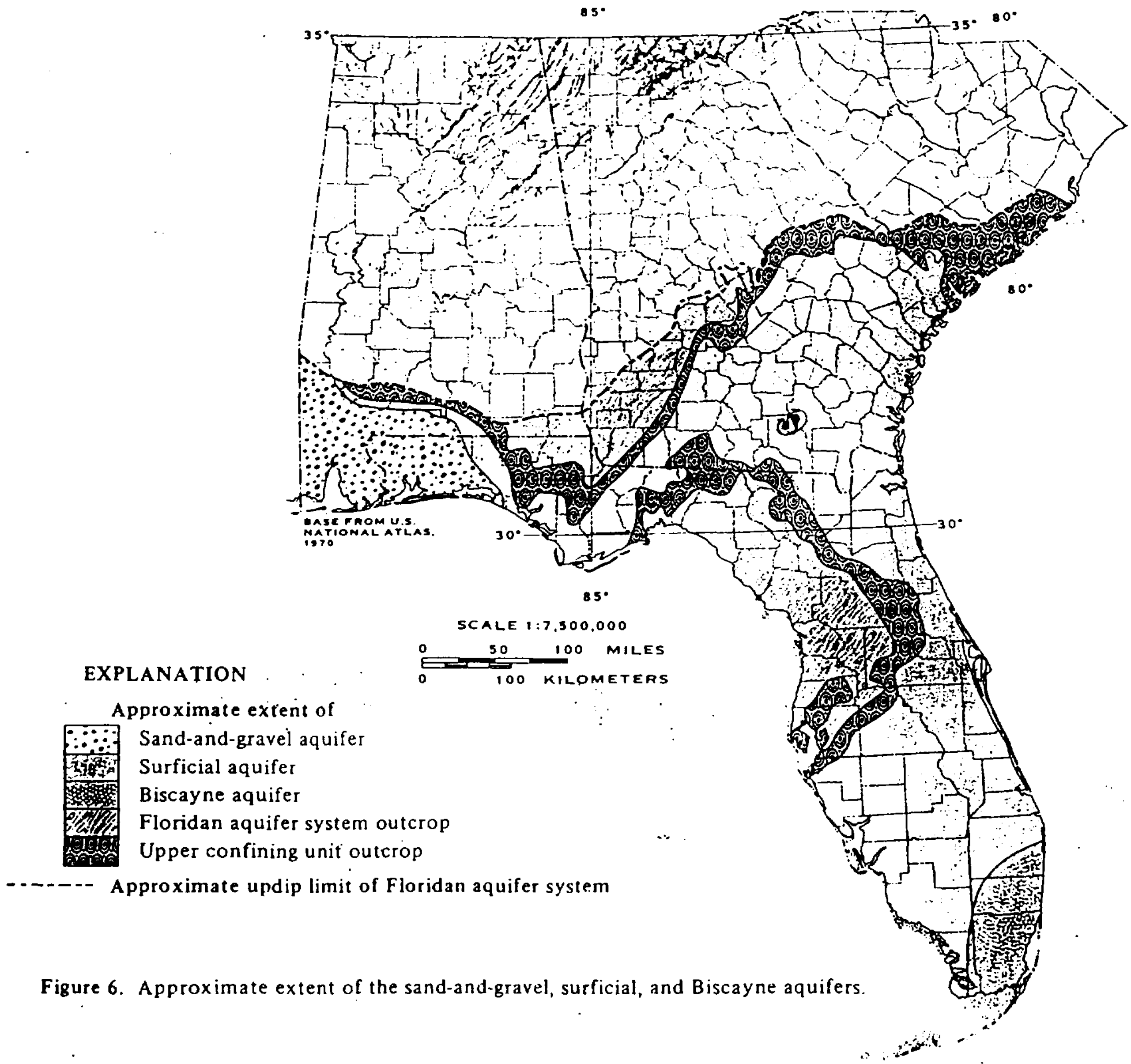


Figure 6. Approximate extent of the sand-and-gravel, surficial, and Biscayne aquifers.

aquifer. In such areas, the surficial aquifer is considered a hydraulic "sink." The thickness and lithologic character of the confining beds that separate the surficial aquifer from the Floridan aquifer system determine the degree of hydraulic interconnection between the two.

The surficial aquifer in the strict sense as mapped on figure 6 consists of all surficial strata containing water under unconfined conditions other than the Biscayne and sand-and-gravel aquifers. Given these restrictions, the surficial aquifer consists mostly of unconsolidated sand and shelly sand deposits that are predominantly of Holocene age but in places include deposits of Pleistocene and Pliocene age. For example, Pleistocene sands that are preserved as ancient beach and shoreline deposits, offshore bars, and the flows of marine terraces (Healy, 1975) are part of the surficial aquifer. Klein (1972) and Hyde (1975) included shell beds and sands of the Anastasia Formation (Pleistocene) and limestones of the Tamiami Formation (Pliocene) in southern Florida in a nonartesian aquifer that they termed the "shallow aquifer"—the equivalent of the surficial aquifer of this report. Callahan (1964) thought that the surficial "sand aquifer" in Georgia consisted of Pliocene to Holocene sands that reach a thickness of about 100 ft in southeastern Georgia. Klein (1972) recorded 130 ft of surficial aquifer in southwestern Florida. The maximum measured thickness of the surficial aquifer recorded during this study is 325 ft in well GA-COF-1 in Coffee County, Ga.

Because the sands designated surficial aquifer on figure 6 are mostly thin and discontinuous in places, water is produced from them primarily for domestic use. Where no other source of ground water exists and the surficial aquifer is sufficiently thick, the aquifer supplies water for industrial or municipal use. Highly permeable strata containing water under nonartesian conditions are the principal source of supply for large municipalities in two areas. These strata are the lateral equivalents of the surficial aquifer. In southeastern Florida, these highly permeable rocks are called the Biscayne aquifer (fig. 6); in extreme western panhandle Florida and south Alabama, they are called the sand-and-gravel aquifer.

The Biscayne aquifer is the source of supply for all municipal water systems in the Palm Beach-Miami area of Florida. Over 500 Mgal/d of water are currently pumped from the Biscayne (Klein and Hull, 1978). The Biscayne is a wedge-shaped body of highly permeable limestone, sandstone, and sand that thickens from a featheredge at its western boundary to more than 200 ft near the Atlantic coast in eastern Broward County (well FLA-BRO-1). The sand content of the aquifer is higher to the north and east; limestone and sandstone are more prominent to the south and west. Included in the Biscayne aquifer are several sand and limestone units of Pleistocene age, the Pliocene and Pleistocene Caloosahatchee Formation, and the upper part of the Pliocene Tamiami Formation (Franks, 1982). Permeability is highest in those areas where the aquifer is mostly limestone, partly because of the development of solution cavities in the limestone. In limestone-rich areas, the transmissivity of the Biscayne aquifer is greater than 1.6×10^6 ft^2/d, but decreases to about 5.4×10^4 ft^2/d where the aquifer is mostly sand (Klein and Hull, 1978). Because of its high permeability and because it is intensively used as a source of water, the Biscayne is subject to contamination by saltwater intrusion from the ocean and by infiltration from an extensive system of canals cut into it that are connected to the ocean. The Biscayne is everywhere separated from the Floridan aquifer system by a thick sequence of low-permeability argillaceous rocks that are mostly of Miocene age. More detailed discussions of the Biscayne aquifer have been given byParker and others (1955), Schroeder and others (1958), Klein and Hull (1978), and Franks (1982).

The sand-and-gravel aquifer (fig. 6) consists primarily of quartz sand that contains much gravel-sized quartz as disseminated particles and as layers. Geologic units included by Franks (1982) in the sand-and-gravel aquifer are, from oldest to youngest, (1) coarse clastics that are probably equivalent to part of the Alum Bluff Group of Miocene age, (2) the Pliocene Citronelle Formation, (3) undifferentiated Pleistocene terrace deposits, and (4) Holocene alluvium. The aquifer thickens southward and westward from a featheredge in southern Alabama and in Walton County, Fla., to a maximum measured thickness of about 1,400 ft in well ALA-MOB-17 in Mobile County, Ala. Locally, layers and lenses of clay within the aquifer form semiconfining beds and create confined conditions in the permeable materials that lie between clay beds. For the most part, however, water in the sand-and-gravel aquifer is unconfined. The aquifer is the primary source of ground water in western panhandle Florida and southwestern Alabama. In places near its updip limit, the sand-and-gravel aquifer is in direct hydraulic contact with the Floridan aquifer system. However, the two aquifers are for the most part separated by thick clay beds. The transmissivity of the sand-and-gravel aquifer is locally as high as about 2×10^4 ft^2/d (Musgrove and others, 1961). Detailed descriptions of the geology and hydrologic characteristics of the sand-and-gravel aquifer have been presented by Musgrove and others (1961), Barraclough and Marsh (1962), Marsh (1966), Trapp (1978), and Franks (1982).

UPPER CONFINING UNIT

Over much of the study area, the Floridan aquifer system is overlain by an upper confining unit that consists mostly of clastic rocks but locally contains much low-permeability limestone and dolomite in its lower parts. In places, the upper confining unit has been removed by erosion, and the Floridan either crops out or is covered by only a thin veneer of permeable sand that is part of the surficial aquifer. Because the lithology and thickness of the upper confining unit are highly variable, the unit retards the vertical movement of water between the surficial aquifer and the Floridan aquifer system in varying degrees. Where the upper confining unit is thick or where it contains much clay, leakance through the unit is much less than where it is thin or highly sandy. In these thick or clay-rich areas, therefore, water in the surficial aquifer moves mostly laterally and is discharged into surface-water bodies rather than moving downward through the upper confining unit (when the head differential is favorable) to recharge the Floridan aquifer system.

The upper confining unit may be breached locally by sinkholes and other openings that serve to connect the Floridan aquifer system directly with the surface. These sinkholes are for the most part found where the thickness of the upper confining unit is 100 ft or less. They appear to result from the collapse of a relatively thin cover of clastic materials into solution features developed in the underlying limestone of the Floridan aquifer system rather than from the solution of limestone beds within the upper confining unit itself. The upper confining unit is generally more sandy where it is less than 100 ft thick because these relatively thin areas represent upbasin depositional sites where coarser clastic rocks were laid down. Plate 25 shows the extent and thickness of the upper confining unit. The maximum measured thickness of the unit is about 1,890 ft in well ALA-BAL-30 in Baldwin County, Ala. The maximum contoured thickness is 1,900 ft. Plate 25 also shows areas where water in the Floridan aquifer system occurs under unconfined, thinly confined (thickness of upper confining unit between 0 and 100 ft), and confined conditions.

The upper confining unit includes all beds of late and middle Miocene age, where such beds are present. Locally, low-permeability beds of post-Miocene age are part of the upper confining unit. Over most of the study area, middle Miocene and younger strata consist of complexly interbedded, locally highly phosphatic sand, clay, and sandy clay beds, all of which are of low permeability in comparison with the underlying limestone of the Floridan aquifer system. Locally, low-permeability carbonate rocks that are part of the lower Miocene Tampa Limestone or of the Oligocene Suwannee Limestone are included in the upper confining unit. Very locally, in the West Palm Beach, Fla., area, the uppermost beds of rocks of late Eocene age are of low permeability and are included in the upper confining unit.

Parker and others (1955) and Stringfield (1966) included basal beds of the Hawthorn Formation in their Floridan and principal artesian aquifers where those beds are permeable. In a few isolated cases (for example, in Brevard County, Fla.), the lowermost Hawthorn strata are indeed somewhat permeable, but their permeability is considerably less than that of the underlying Floridan aquifer system, as Parker and others (1955, p. 84) recognized. Locally, in parts of southwestern Florida (Sutcliffe, 1975; Boggess and O'Donnell, 1982) and west-central peninsular Florida (Ryder, 1982), permeable zones within the Hawthorn Formation are an important source of ground water over a one- or two-county area. Although some of these permeable zones are limestones, their transmissivity is at least an order of magnitude less than that of the Floridan aquifer system, and they are separated from the main body of permeable limestone (Floridan) by thick confining beds. Because of their limited areal extent, relatively low permeability, and vertical separation from the Floridan aquifer system practically everywhere, water-bearing Hawthorn limestones are excluded from the Floridan in this report.

Where the limestone and dolomite of the Floridan crop out, a clayey residuum may form over the carbonate rocks as a result of chemical weathering that dissolves the carbonate minerals and concentrates trace amounts of clay that are in them. Such residumm is particularly well developed in the Dougherty Plain area of southwestern Georgia (Hayes and others, 1983). Although this residuum is a low-permeability material and may very locally form a semiconfining layer above the limestone, it is usually thin and laterally discontinuous. Accordingly, the clayey residuum is not included in this report as part of the upper confining unit of the Floridan aquifer system.

Because the rocks that comprise the upper confining unit vary greatly in lithology, are complexly interbedded, and for the most part are of low permeability, little is known about their hydraulic characteristics. Where clay beds are found in the Hawthorn Formation, they are usually very effective confining beds. Vertical hydraulic conductivity values for Hawthorn clays, as established from core analysis and from aquifer tests, range from 1.5×10^{-2} ft/d (Hayes, 1979) to 7.8×10^{-7} ft/d (Miller and others, 1978). Where sandy beds of the Hawthorn comprise a local aquifer, transmissivity values for the sand range as high as about 13,000 ft^2/d (Ryder, 1982). Hawthorn limestone beds that are local aquifers yield up to 750 gal/min (Boggess, 1974).

FLORIDAN AQUIFER SYSTEM

GENERAL

The Floridan aquifer system is a thick sequence of carbonate rocks generally referred to in the literature as the "Floridan aquifer" in Florida and the "principal artesian aquifer" in Georgia, Alabama, and South Carolina. As defined in this report, the Floridan aquifer system encompasses more of the geologic section and extends over a wider geographic area than either the Floridan or the principal artesian aquifer, as those aquifers have been described in the literature. Figure 7 shows the geologic formations in Florida and southeastern Georgia that were called "principal artesian formations" by Stringfield (1936), those that were included in the "Floridan aquifer" as defined by Parker and others (1955), and those placed in the "principal artesian aquifer" as defined by Stringfield (1966). Subsequent deep drilling and hydraulic testing have shown that highly permeable carbonate rocks extend to deeper stratigraphic horizons than those included in either the "Floridan" or "principal artesian" aquifers as originally described. Accordingly, this author (cited by Franks, 1982) extended the base of the Floridan aquifer downward to include part of the upper Cedar Keys Limestone (fig. 7). Limestone and dolomite beds that commonly occur at the base of the Hawthorn Formation have been included as part of the "Floridan" or "principal artesian" aquifer in most previous reports. However, data collected for the present study show that, except very locally, there are no high-permeability carbonate rocks in the lower part of the Hawthorn Formation that are in direct hydraulic contact with the main body of the Floridan aquifer system.

The Hawthorn Formation was thus excluded from the aquifer system in a report by Miller (1982a) that was one of a series of several interim reports published during the present study. In these interim reports, the aquifer system was called the "Tertiary limestone aquifer system of the Southeastern United States." This cumbersome, albeit more accurate, terminology has subsequently been abandoned, and the aquifer system is referred to in this professional paper as the "Floridan aquifer system" (see Johnston and Bush, 1985 for a more detailed history of the terminology applied to the aquifer system).

The Floridan aquifer system is defined in this report

EPOCH		Stringfield (1936) Formation	Stringfield (1936) Aquifer	Parker and others (1955) Formation	Parker and others (1955) Aquifer	Stringfield (1966) Formation	Stringfield (1966) Aquifer	Miller, in Franks (1982) Formation	Miller, in Franks (1982) Aquifer	Miller (1982 a,c) Formation	Miller (1982 a,c) Aquifer system	This Report Formation	This Report Aquifer system
MIOCENE	Middle	Hawthorn Formation		Hawthorn Formation		Hawthorn Formation		Hawthorn Formation		Hawthorn Formation		Hawthorn Formation	
	Early	Tampa Limestone	Principal artesian formations	Tampa Limestone	Where Permeable	Tampa Limestone	Principal artesian aquifer	Tampa Limestone	Where Permeable	Tampa Limestone	Where Permeable	Tampa Limestone	Where Permeable
OLIGOCENE		Oligocene Limestone		Suwannee Limestone	Floridan aquifer	Suwannee Limestone		Suwannee Limestone	Floridan aquifer	Suwannee Limestone	Tertiary limestone aquifer system	Suwannee Limestone	Floridan aquifer system
EOCENE	Late	Ocala Limestone		Ocala Limestone		Ocala Limestone		Ocala Limestone		Ocala Limestone		Ocala Limestone	
	Middle			Avon Park Limestone; Lake City Limestone		Avon Park Limestone; Lake City Limestone		Avon Park-Lake City Limestones		Avon Park-Lake City Limestones		Avon Park Formation	
	Early					Oldsmar Limestone		Oldsmar Limestone		Oldsmar Limestone		Oldsmar Formation	
PALEOCENE								Cedar Keys Limestone		Cedar Keys Limestone		Cedar Keys Formation	

Figure 7. Comparison of aquifer terminologies.

as a vertically continuous sequence of carbonate rocks of generally high permeability that are mostly of middle and late Tertiary age and hydraulically connected in varying degrees and whose permeability is, in general, an order to several orders of magnitude greater than that of those rocks that bound the system above and below. As plate 2 shows, the Floridan aquifer system includes units of late Paleocene to early Miocene age. Very locally, in the Brunswick, Ga., area, the entire Paleocene section plus a thick sequence of rocks of Late Cretaceous age are part of the aquifer system. In and just downdip of the area where the aquifer system crops out, the entire system consists of one vertically continuous permeable unit. Farther downdip, less permeable carbonate units of subregional extent separate the system into two aquifers, herein called the Upper and Lower Floridan aquifers (fig. 8). These less permeable units may be very leaky to virtually nonleaky, depending on the lithologic character of the rock comprising the unit. Because they lie at considerable depth, the hydrologic character and the importance of the subregional low-permeability units are known from only a few scattered deep test wells. Local low-permeability zones may occur within either the Upper or the Lower Floridan aquifer. In places (for example, southeastern Florida), low-permeability rocks account for slightly more than half of the rocks included in the aquifer system.

Even though the rocks that comprise the base of the Upper Floridan aquifer are not everywhere at the same altitude or geologic horizon or of the same rock type, the presence of a middle confining unit over about two-thirds of the study area has led to a conceptual model for the Floridan aquifer system that consists of two active permeable zones (the Upper and Lower Floridan aquifers) separated by a zone of low permeability (a middle confining unit). Because of this simplified layering scheme, it is necessary to greatly generalize the highly complex sequence of high- and low-permeability rocks that comprise the aquifer system. Local confining beds (see, for example, cross section E-E', pl. 21) are either disregarded because they are regionally unimportant or lumped with one of the major layers. The purpose of the conceptual model, and of the digital computer model derived from it and described by Bush and Johnston (1985) is to portray the major aspects of ground-water flow within the Floridan aquifer system. In like manner, the descrip-

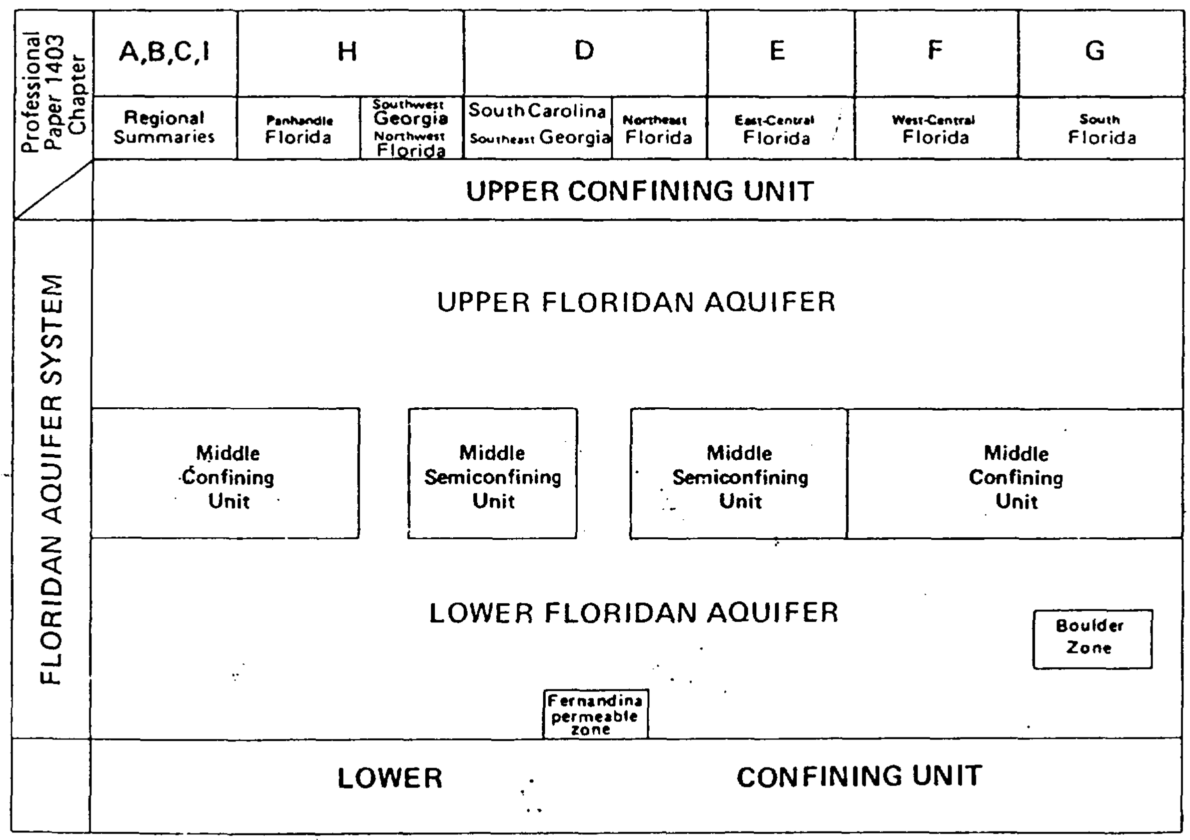


Figure 8. Aquifers and confining units of the Floridan aquifer system.

tion of the aquifer system's geohydrologic framework in this report is intended to show the principal variations in permeability within the aquifer system. In both cases, local anomalies that do not fit with overall (regional) conditions are ignored.

Regionally, the top of the Floridan aquifer system in most places lies at the top of rocks of Oligocene age (Suwannee Limestone) where these strata are preserved. Where Oligocene rocks are absent, the aquifer system's top is generally at the top of upper Eocene rocks (Ocala Limestone). Locally, in eastern panhandle Florida and in west-central peninsular Florida, rocks of early Miocene age (Tampa Limestone) are highly permeable and hydraulically connected to the aquifer system. In places, upper Eocene through lower Miocene rocks are either missing owing to erosion or nondeposition or of low permeability; at these places, rocks of middle Eocene age (Avon Park Formation) mark the top of the aquifer system. It is important to note that there are some places where the upper part of a given formation that comprises the top of the aquifer system consists of low-permeability rocks. At such places, the low-permeability beds are excluded from the aquifer system, and the top of the system is considered to be the top of the uppermost high-permeability carbonate rock. The top of the system, then, may lie within a stratigraphic unit rather than at its top. Because the permeability contrast between the aquifer system and its upper confining unit does not everywhere follow stratigraphic horizons, neither does the top of the aquifer system. Likewise, the top of the aquifer system may locally lie within a limestone unit if the upper part of the limestone consists of low-permeability rock and the lower part is highly permeable.

The time-stratigraphic units or parts of units that mark the top of the Floridan aquifer system at selected localities are shown in figure 9, as well as the time-rock units that comprise the Upper and Lower Floridan aquifers and the units that are considered to represent the aquifer system's base. Figure 9 shows a series of idealized chronostratigraphic columns compiled from well data at several locations in the study area, along with the permeability characteristics of each chronostratigraphic unit at each location. Examination of this figure shows that, in addition to the variations in the top and base of the aquifer system, the degree of complexity varies greatly within the system. Generally speaking (and as figure 9 shows), the aquifer system in most places can be divided into an Upper and Lower Floridan aquifer separated by less-permeable rock. In places, however, no middle confining unit exists (for example, the Baxley, Ga., and Gainesville, Fla., columns on fig. 9), and the aquifer system is highly permeable throughout its vertical extent. In other places, thick sequences of low-permeability rock occur at several levels within the aquifer system (for example, the Savannah, Ga., and West Palm Beach, Fla., areas in fig. 9), and the several discrete permeable zones of the system may be hydraulically separated.

Regionally, and in a fashion similar to the way in which the top is defined, the base of the aquifer system is defined as the level below which there is no high-permeability carbonate rock. The base of the system is generally either (1) glauconitic, calcareous, argillaceous to arenaceous rock that ranges in age from late Eocene to late Paleocene (fig. 9) or (2) massively bedded anhydrite that commonly occurs in the lower two-thirds of the Paleocene Cedar Keys Formation. Locally, near Brunswick, Ga., micritic limestone and argillaceous limestone of Late Cretaceous (Tayloran) age mark the base of the aquifer system. The permeability of the micritic and argillaceous carbonate rocks, the anhydrite beds, and the various clastic rocks that comprise the base of the system is much less than that of the carbonate rocks above. Regardless of its lithologic character, the lower confining unit, whose top is mapped in this report as the base of the aquifer system, everywhere separates the system from deeper, predominantly clastic aquifers of early Tertiary and Late Cretaceous age.

The upper confining unit of the Floridan aquifer system generally consists of rocks of middle and late Miocene age. Where older rocks such as the lower Miocene Tampa or Oligocene Suwannee Limestones are of low permeability, they are also included in the upper confining unit. In parts of the study area, the upper confining unit has been removed by erosion and the aquifer system either: crops out, is covered by only a surficial sand aquifer, or is covered very locally by clayey residuum. Hydraulic conditions within the aquifer system accordingly vary from confined to unconfined. Where thick sequences of less permeable rocks of subregional extent are present within the aquifer system, they divide it into two major aquifers. The uppermost aquifer (Upper Floridan) generally consists of rocks of Oligocene, late Eocene, and late middle Eocene age (fig. 9). The lower aquifer (Lower Floridan) generally consists of rocks of early middle Eocene to late Paleocene age. Where no middle confining unit separates the two aquifers, all the permeable rock comprising the aquifer system is referred to as the Upper Floridan aquifer. The middle confining unit separating the Upper and Lower Floridan aquifers is generally found in the middle part of rocks of middle Eocene age. The less permeable material that comprises the middle confining unit, however, is not everywhere of the same age (fig. 9), nor does it everywhere consist of the same rock type, as a later section of this report discusses in detail.

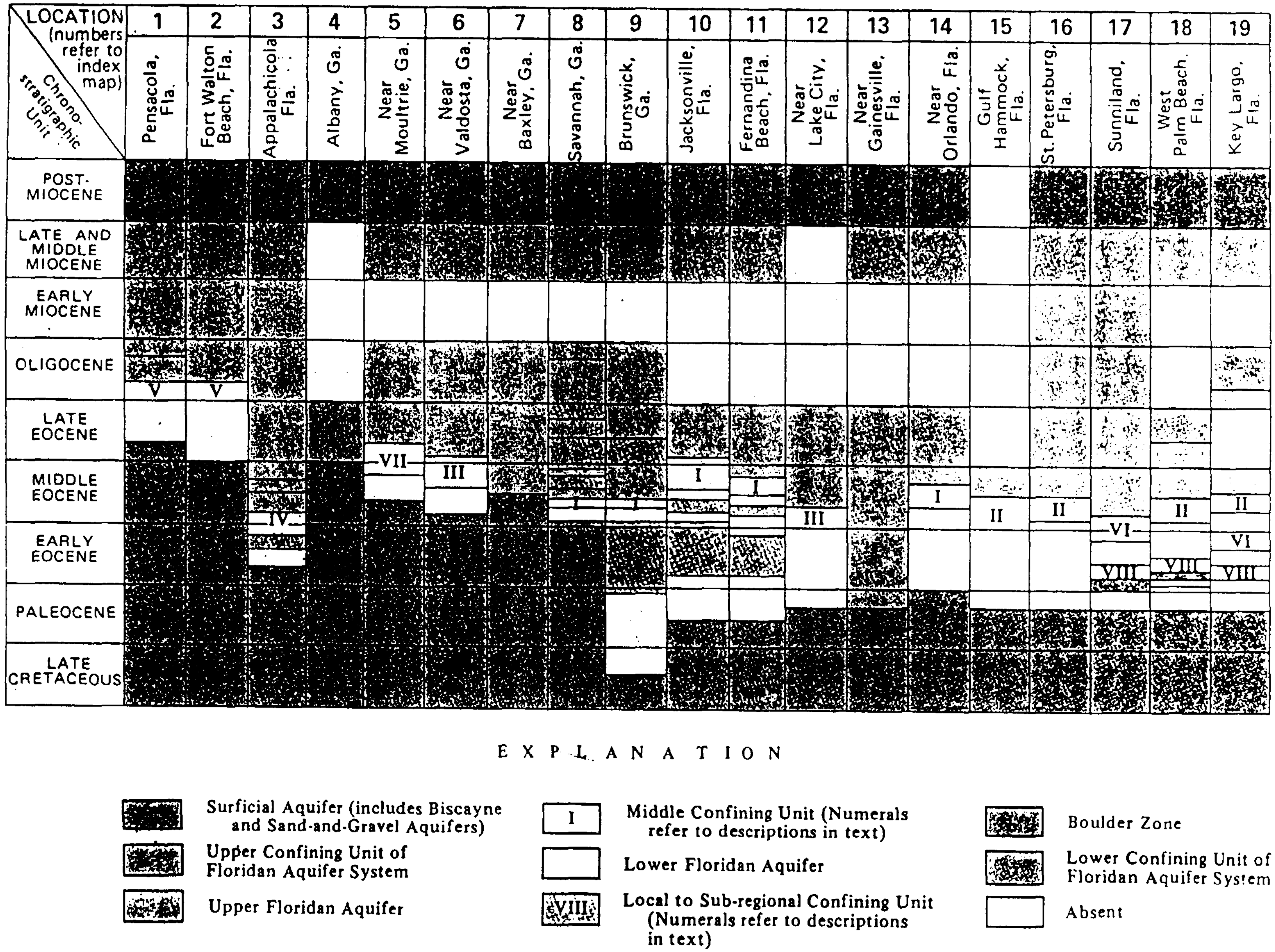


Figure 9. Relation of time-stratigraphic units to the Floridan aquifer system, its component aquifers, and its confining units.

Throughout much of the study area, the water in the Lower Floridan is brackish to saline. The Lower Floridan is moderately to highly porous, and digital simulation indicates that it transmits water sluggishly (see Bush and Johnston, 1985). Little is known about the Lower Floridan aquifer because in most places there is no reason to drill into a deep aquifer containing poor-quality water when an adequate shallower source of good-quality water (the Upper Floridan aquifer) exists.

Local to subregional zones of cavernous permeability occur at several levels within the Floridan aquifer system. The best known of these zones, called the "Boulder Zone" (Kohout, 1965) because of its difficult drilling characteristics, is found in the lower part of rocks of early Eocene age (fig. 9) in southern Florida. Borehole televiewer surveys show that this zone consists of a series of thin to moderately thick horizontal openings connected vertically by fractures, some of which have been opened and enlarged into vertical tubes by solution. The Boulder Zone resembles modern cave systems and is presumed to have formed in a similar fashion—by solution at or above an early Eocene paleowater table. As a result, the transmissivity of the Boulder Zone is extremely high (Meyer, 1974). Other shallower, less extensive cavernous zones are found farther north in the Florida peninsula (Miller, 1979). Where these cavernous zones are developed in the parts of the aquifer system that contain saline water, they are used as receiving zones for underground injection of treated sewage and other industrial wastes.

Within the sequence of rocks that is here treated as an upper confining unit are permeable zones that extend over part of a county or over several counties and that are important local sources of water. These localized artesian aquifers are considered in this report to comprise part of the upper confining unit of the Floridan aquifer system because their permeability is low in comparison with that of the Floridan and because they are of limited extent.

EXTENT

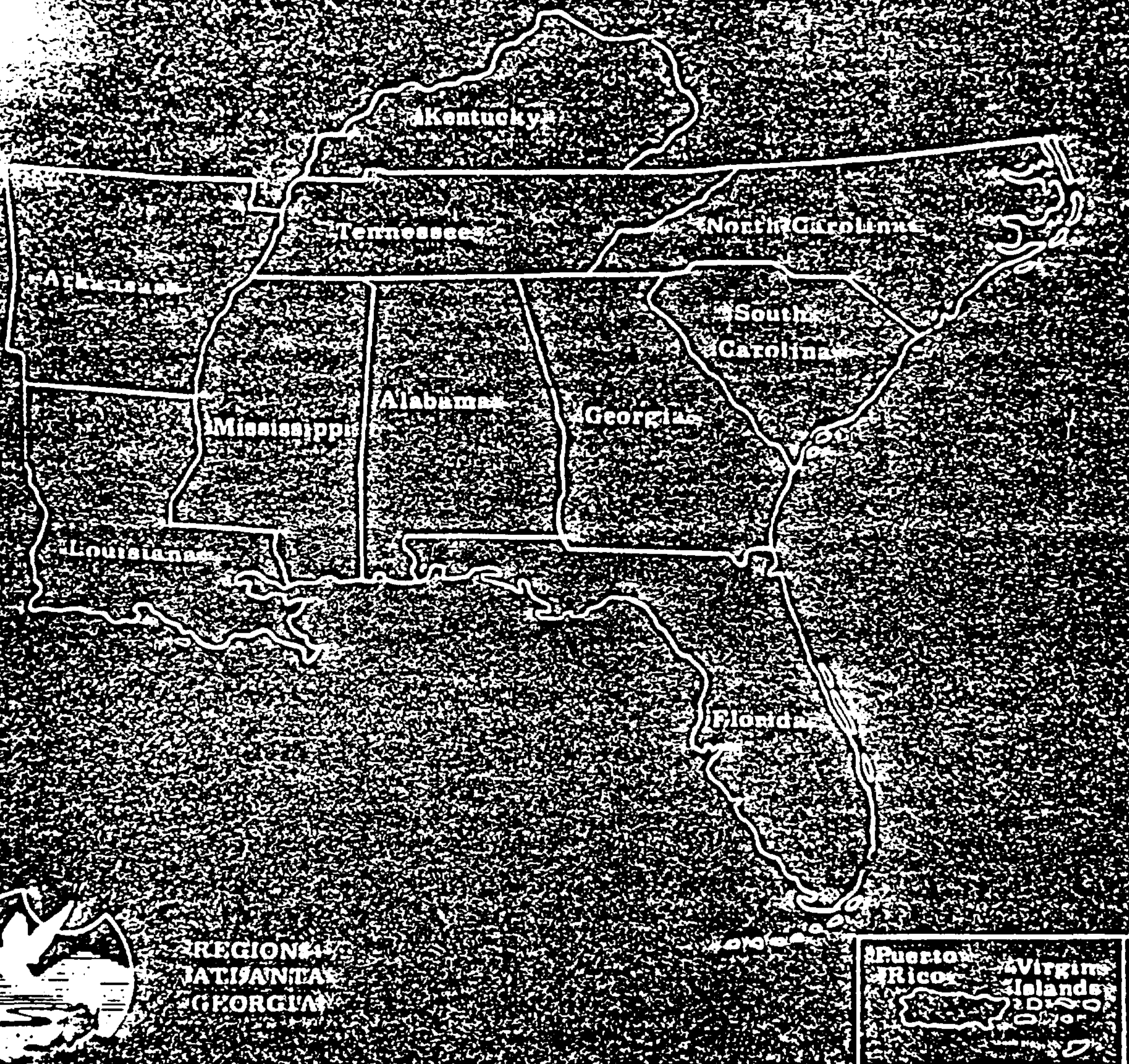
The Floridan aquifer system becomes thin in updip areas where it is interbedded with clastic rocks. The limestones that comprise the aquifer system grade in an updip direction into sandy or argillaceous limestone, which in turn grades into calcareous sand or clay. Still farther updip, these calcareous clastic rocks grade into fully clastic sediments that are stratigraphically equivalent to the aquifer system but are much less permeable than their limestone equivalents. The updip facies change from limestone into clastic rocks and the corresponding decrease in the amount of highly permeable rock in an updip direction are shown by geohydrologic cross-sections A-A', B-B', C-C', D-D' and O'-O'' (pl. 15, 16, 18, 19, 20). The updip limit of the Floridan aquifer system (plate 26) has been arbitrarily placed where the thickness of the system is less than 100 ft and where the clastic rocks interbedded with the limestone make up more than 50 percent of the rock column between the uppermost and lowermost limestone beds that can be shown to be connected downdip. To the north and west of the line shown as the approximate updip limit of the aquifer system, thin beds, lenses, and stringers of limestone may be either connected to the main limestone body or isolated from it because of postdepositional erosion. Although these thin beds and outliers locally yield water in small to moderate amounts, they are not considered in this report to be part of the Floridan aquifer system.

The Floridan aquifer system is known to extend offshore from Georgia (McCollum and Herrick, 1964) and peninsular Florida (Rosenau and others, 1977; Schlee, 1977; Johnston and others, 1982). Because offshore geologic and hydrologic data are sparse, however, the aquifer system is not mapped offshore in this report. The Floridan contains fresh to brackish water in some offshore areas (Johnston and others, 1982), but sparse data on water quality mandate mapping of the aquifer system's freshwater-saltwater interface by indirect methods (Bush and Johnston, 1985; Sprinkle, 1985).

In part of the mapped area in South Carolina, the Upper Floridan aquifer has passed by facies change into low-permeability clastic rocks, and only the Lower Floridan aquifer is present. The effect is that of a pinchout of the Upper Floridan. The approximate area of facies change within the Upper Floridan is shown on plate 26 by a dashed northwest-trending line whose location is based on widely scattered well control. Contours to the northeast of the line represent the top of a middle confining unit that is underlain by the Lower Floridan aquifer at an altitude several hundred feet lower. Other water-bearing limestone units in South Carolina are located northeast of the area mapped in this report, but they are either hydraulically separate from the Floridan aquifer system or their permeability is too low to warrant including them in the system.

A series of faults in southwestern Alabama shown on plate 26 marks the updip limit of the aquifer system. These arcuate faults, which are part of the Gilbertown-Pickens-Pollard fault zone, bound a series of grabens. Movement along these faults has juxtaposed low-permeability clastic rocks within the grabens opposite the permeable limestone that comprises the aquifer system. The north-trending, sinuous, fault-bounded feature in Washington and Mobile Counties,

ENDANGERED AND THREATENED SPECIES OF THE SOUTHEASTERN UNITED STATES



REGION 4
ATLANTA
GEORGIA

[redacted]

[redacted]

United States Department of the Interior

FISH AND WILDLIFE SERVICE
75 SPRING STREET, S.W.
ATLANTA, GEORGIA 30303

August 23, 1985

NOTICE

TO: All Project Leaders and Cooperators

FROM: Endangered Species Office, Federal Assistance, FWS, Atlanta, Georgia

SUBJECT: Changes to the Region 4 Endangered Species Notebook

This update covers the following actions: listing of the Carolina northern flying squirrel in North Carolina and Tennessee as endangered, listing of the Tar River spiny mussel in North Carolina as endangered, listing of five Florida pine rockland plants as endangered, listing of the Miccosukee gooseberry in Florida and South Carolina as endangered, listing of Ruth's golden aster in Tennessee and Vahl's boxwood in Puerto Rico as endangered, listing of the amber darter and Conasauga logperch in Georgia and Tennessee as endangered with critical habitat designated, reclassification of the alligator in Florida to threatened by similarity of appearance, and the proposed listing of two plants (pondberry and Florida golden aster).

REGIONAL LIST: Replace.

STATE LISTS: Replace FL, GA, NC, PR, SC, TN.

CRITICAL HABITAT: Replace index; add amber darter and Conasauga logperch designations for GA and TN.

PROPOSED RULEMAKING: Replace previous sheet.

Species Accounts: FISHES - Replace index; add accounts for two fishes.

PLANTS - Replace index; add accounts for eight plants.

Attachments

85-3

Federally Listed Species by State

GEORGIA

(E=Endangered; T=Threatened; CH=Critical Habitat determined)

Mammals	General Distribution
Bat, gray (Myotis grisescens) - E	Northwest, West
Bat, Indiana (Myotis sodalis) - E	Extreme Northwest
Manatee, Florida (Trichechus manatus) - E	Coastal waters
Panther, Florida (Felis concolor coryi) - E	Entire state
Whale, right (Eubalaena glacialis) - E	Coastal waters
Whale, finback (Balaenoptera physalus) - E	Coastal waters
Whale, humpback (Megaptera novaeangliae) - E	Coastal waters
Whale, sei (Balaenoptera borealis) - E	Coastal waters
Whale, sperm (Physeter catodon) - E	Coastal waters

Birds	
Eagle, bald (Haliaeetus leucocephalus) - E	Entire state
Falcon, American peregrine (Falco peregrinus anatum) - E	North
Falcon, Arctic peregrine (Falco peregrinus tundrius) - T	Coast, Northwest
Stork, wood (Mycteria americana) - E	Southeastern swamps
Warbler, Bachman's (Vermivora bachmanii) - E	Entire state
Warbler, Kirtland's (Dendroica kirtlandii) - E	Coast
Woodpecker, ivory-billed (Campephilus principalis) - E	South, Southwest
Woodpecker, red-cockaded (Picoides (=Dendrocopos) borealis) - E	Entire state

Reptiles	
Alligator, American (Alligator mississippiensis) - E	Inland coastal plain
Alligator, American (Alligator mississippiensis) - T	Coastal areas

GEORGIA (cont'd)

	General Distribution
Snake, eastern indigo (*Drymarchon corais couperi*) - T	Southeast
Turtle, Kemp's (Atlantic) ridley (*Lepidochelys kempii*) - E	Coastal waters
Turtle, green (*Chelonia mydas*) - T	Coastal waters
Turtle, hawksbill (*Eretmochelys imbricata*) - E	Coastal waters
Turtle, leatherback (*Dermochelys coriacea*) - E	Coastal waters
Turtle, loggerhead (*Caretta caretta*) - T	Coastal waters

Fishes

Darter, amber (*Percina antesella*) - E,CH	Conasauga R., Murray County
Darter, snail (*Percina tanasi*) - T	S. Chickamauga Cr., Catoosa County
Logperch, Conasauga (*Percina jenkinsi*) - E,CH	Conasauga R., Murray County
Sturgeon, shortnose (*Acipenser brevirostrum*) - E	Coastal rivers

Plants

Florida torreya (*Torreya taxifolia*) - E	Decatur County
Green pitcher plant (*Sarracenia oreophila*) - E	Towns County
Hairy rattleweed (*Baptisia arachnifera*) - E	Wayne, Brantley Counties
Persistent trillium (*Trillium persistens*) - E	Tallulah-Tugaloo River system, Rabun and Habersham Counties

REFERENCE 6

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

REGION IV

345 COURTLAND STREET, N.E.
ATLANTA, GEORGIA 30365

MEMORANDUM

DATE: September 22, 1994

SUBJECT: Record of Telephone Con
RE: Waycross Army Airf

TO: file

FROM: Gerald Foree 9.907.
Site Assessment Section
Waste Management Divisi

Talked with Charles McClellan er
Department on Thursday, Septem ng
information was obtained:

* the Waycross Army Airfi th
approximately 10 different industries

* the City of Waycross has 2 water systems

* system #1, located in the city limits, has 3 wells at depths of approximately 700 ft in the Floridan Aquifer that pumps approximately 2.5 million gallons/dy

* system #2, located at the Industrial Park, has 2 wells at the same depths mentioned above that pumps approximately 200,000 gallons/dy

* system serves approximately 15,000 people within the Waycross City limits

* there are also 2 industrial wells located at Champion Bldg Materials and Waycross Molded which both are located in the Industrial Park

* Kettle Creek flows in a northeasterly direction into the Satilla River

* there are no surface water intakes located in the Satilla River, but there is some recreational fishing and swimming

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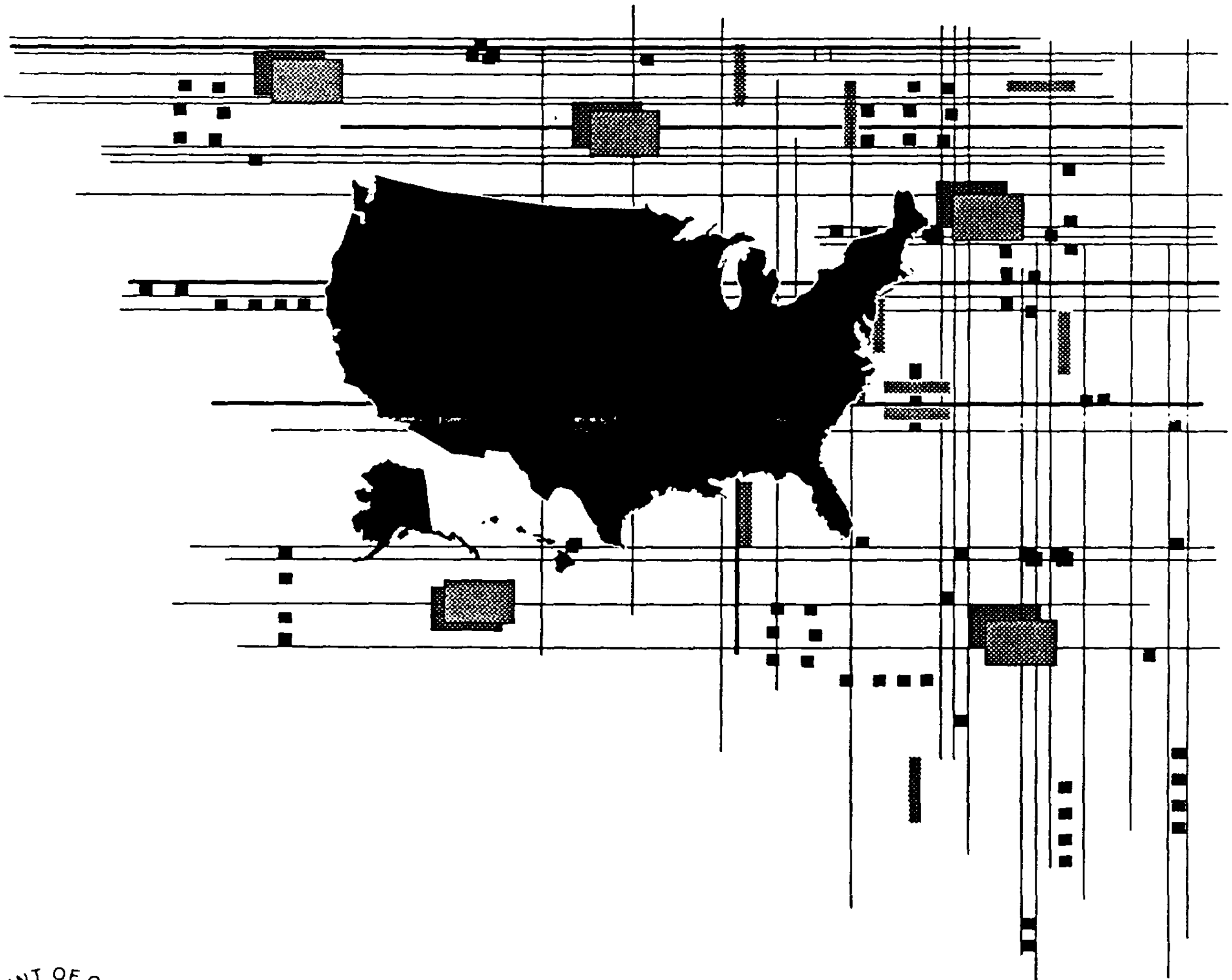
Estimates of Households, for Counties: July 1, 1985



DEPARTMENT OF COMMERCE 75 UNITED STATES

U.S. Department of Commerce
BUREAU OF THE CENSUS

Table 1. Estimates of Households, for Counties: July 1, 1985—Continued

(A dash (-) represents zero or rounds to zero. Estimates are consistent with special censuses since 1980. Corrections to 1980 census counts are not included. See text concerning rounding and average population per household)

State and county	Households: July 1, 1985 (estimate)	Households: April 1, 1980 (census)	Households: Change, 1980-85: Number	Households: Change, 1980-85: Percent	Average population per household: July 1, 1985 (estimate)	Average population per household: April 1, 1980 (census)	Population: July 1, 1985 (estimate)	Population: April 1, 1980 (census)	Population: Change, 1980-85: Number	Population: Change, 1980-85: Percent
Georgia—Continued										
Turner	3,100	3,078	-	-0.1	3.05	3.06	9,500	9,510	-100	-0.5
Twiggs	3,200	2,812	400	15.6	3.10	3.28	10,200	9,354	800	9.0
Union	3,900	3,369	500	15.0	2.69	2.76	10,500	9,390	1,200	12.3
Upson	9,700	9,170	500	5.6	2.68	2.80	26,300	25,998	300	1.2
Walker	20,600	19,634	900	4.7	2.72	2.86	56,200	56,470	-300	-0.5
Walton	11,000	10,006	1,000	10.0	2.96	3.09	32,800	31,211	1,600	5.2
Ware	13,300	12,788	500	4.1	2.73	2.85	37,200	37,180	-	-0.1
Warren	2,000	2,110	-100	-5.8	3.09	3.07	6,200	6,583	-300	-5.2
Washington	6,400	6,076	300	5.6	2.99	3.07	19,400	18,842	500	2.9
Wayne	7,600	6,879	800	11.2	2.80	2.95	21,900	20,750	1,200	5.7
Webster	700	756	-	-6.1	3.03	3.10	2,200	2,341	-200	-8.0
Wheeler	1,700	1,733	-	-1.3	2.97	2.94	5,100	5,155	-	-0.3
White	4,200	3,499	700	20.9	2.60	2.77	11,400	10,120	1,300	12.4
Whitfield	24,700	22,466	2,200	9.8	2.76	2.91	68,500	65,789	2,800	4.2
Wilcox	2,600	2,596	-	1.0	2.78	2.87	7,500	7,682	-200	-2.1
Wilkes	4,100	3,880	200	5.0	2.73	2.80	11,200	10,951	200	2.2
Wilkinson	3,600	3,350	300	7.7	2.98	3.09	10,800	10,368	400	3.8
Worth	6,000	5,811	200	3.5	3.04	3.08	18,400	18,064	400	2.0
Hawaii	330,000	294,052	36,000	12.4	3.06	3.15	1,051,000	964,691	87,000	9.0
Hawaii	34,900	29,237	5,700	19.4	3.08	3.09	109,500	92,053	17,500	19.0
Honolulu	253,400	230,214	23,200	10.1	3.06	3.15	811,100	762,565	48,500	6.4
Kauai	14,300	12,020	2,300	18.9	3.14	3.22	45,400	39,082	6,300	16.1
Maui	27,700	22,581	5,200	22.8	3.04	3.10	85,500	70,991	14,500	20.4
Idaho	354,000	324,107	30,000	9.2	2.78	2.85	1,004,000	943,935	60,000	6.4
Ada	71,300	63,139	8,100	12.9	2.65	2.69	192,400	173,036	19,400	11.2
Adams	1,200	1,212	-	-2.0	2.83	2.75	3,400	3,347	-	0.6
Bannock	24,300	22,489	1,800	8.1	2.77	2.85	68,800	65,421	3,400	5.2
Bear Lake	2,100	2,211	-100	-5.5	3.20	3.12	6,700	6,931	-200	-2.9
Benewah	3,100	2,932	200	6.5	2.74	2.81	8,600	8,292	300	3.8
Bingham	11,300	10,772	600	5.2	3.35	3.35	38,300	36,489	1,800	5.1
Blaine	5,500	3,978	1,500	38.9	2.34	2.44	13,100	9,841	3,300	33.5
Boise	1,200	1,107	100	9.9	2.53	2.71	3,100	2,999	100	2.6
Bonner	9,700	8,814	800	9.6	2.68	2.73	26,000	24,163	1,800	7.4
Bonneville	23,600	21,307	2,300	10.9	2.95	3.08	70,200	65,980	4,300	6.5
Boundary	2,600	2,479	200	6.3	2.89	2.92	7,700	7,289	400	5.5
Butte	1,100	1,072	-	-0.9	2.94	3.04	3,200	3,342	-100	-4.2
Camas	300	291	-	-11.7	2.69	2.81	700	818	-100	-15.6
Canyon	31,500	28,458	3,000	10.7	2.76	2.86	89,300	83,756	5,600	6.7
Caribou	2,500	2,674	-100	-5.1	3.28	3.22	8,400	8,695	-300	-3.3
Cassia	6,800	6,119	700	10.9	3.03	3.16	20,700	19,427	1,200	6.3
Clark	300	262	-	2.6	2.75	2.99	800	798	-	-5.1
Clearwater	3,600	3,636	-	-0.8	2.69	2.81	10,000	10,390	-400	-4.2
Custer	1,900	1,237	700	56.9	2.68	2.73	5,200	3,385	1,800	54.3
Elmore	7,500	6,832	700	9.6	2.75	2.92	22,300	21,565	700	3.2
Franklin	2,800	2,662	100	4.0	3.42	3.33	9,500	8,895	600	6.7
Fremont	3,200	3,277	-100	-2.6	3.22	3.23	10,500	10,813	-300	-2.9
Gem	4,200	4,219	-	0.3	2.71	2.81	11,600	11,972	-400	-3.1
Gooding	4,300	4,143	200	4.4	2.70	2.77	12,100	11,874	200	2.0
Idaho	5,200	5,150	100	1.5	2.67	2.80	14,300	14,769	-500	-3.1
Jefferson	5,000	4,437	500	11.6	3.28	3.43	16,300	15,304	1,000	6.6
Jerome	5,200	5,084	100	2.1	2.93	2.90	15,300	14,840	500	3.3
Kootenai	24,600	21,404	3,200	15.0	2.68	2.76	66,800	59,770	7,000	11.8
Latah	11,900	10,256	1,600	15.6	2.40	2.52	31,100	28,749	2,300	8.0
Lemhi	2,800	2,681	100	4.4	2.64	2.76	7,500	7,460	-	-0.1

POOR LEGIBILITY

PORTIONS OF THIS DOCUMENT MAY BE UNREADABLE, DUE TO THE QUALITY OF THE ORIGINAL

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION IV
SITE ASSESSMENT SECTION, WASTE PROGRAMS BRANCH
WASTE MANAGEMENT DIVISION
345 COURTLAND STREET, N.E.
ATLANTA, GEORGIA 30365

FACSIMILE TRANSMISSION COVER SHEET

DATE: 9-26-94 NUMBER OF PAGES: (INCLUDE COVER) 1

TO: Ms. Cox ADDRESS: WCI

FAX: 912/2876520 PHONE: 912/2856400

IF THE FOLLOWING MESSAGE IS RECEIVED POORLY, CALL: Gerald Foreé
IN OUR OFFICE AT THE NUMBER SHOWN BELOW.
****

COMMENTS: Per our conversation, I am currently working on an investigation of the Waycross Army Airfield. For my investigation I need the following infomation:

1) # of inmates
2) # of workers
3) # of drinking water wells (if any)
4) depth(s) of wells
5) drinking water source (if # 3 + 4 do not apply)

I can be reached at (404) 3475065 voice mail ext. 6164 if you have any questions and/or problems. Thank you for your cooperation.

Gerald F. Foreé

Gerald F. Foreé

****

MACHINE TYPE

HARRIS/3M
2127

FAX NUMBER: (404) 347-4862

PHONE NUMBER: (404) 347-5059
ext. 6164

GA

DEFENSE ENVIRONMENTAL RESTORATION PROGRAM
FOR FORMERLY USED SITES
INVENTORY PROJECT REPORT
WAYCROSS ARMY AIRFIELD
WAYCROSS, WARE COUNTY, GEORGIA
PROJECT NO. I04GA059200

TABLE OF CONTENTS

PART I - PROJECT DESCRIPTION

PROJECT DESCRIPTION
WAYCROSS ARMY AIRFIELD
WAYCROSS, WARE COUNTY, GEORGIA
PROJECT NO. I04GA059200

1. INTRODUCTION

At the request of the South Atlantic Division, the Savannah District initiated a study and inventory of possible hazardous waste at the former Waycross Army Airfield site, a former Department of Defense (DOD) property, in June 1987.

2. PROJECT DESCRIPTION

A low-level hazardous and toxic waste removal project is proposed to locate, pump out, fill with inert material, and seal an underground storage tank. The tank is a potential source of low-level contaminants.

3. DESCRIPTION OF SITE

a. The former Waycross Army Airfield is currently known as the Waycross/Ware County Airport. It is located in Ware County, northwest of Waycross, between U.S. Highways No. 1 and No. 82. The airport is adjacent to an industrial park and also located next to the county prison. All these facilities are on property which was once owned by the DOD. The public has unrestricted access to the airport, however, the location of the fueling station, which appears to have an underground tank, has limited access. No discoloration of the soil or ground disturbance was observed at this refueling station.

b. The project site is a property acquired for the War Department for use as a main base for combat crew training. A Prisoner of War camp was also located on the property. The area consists of an airfield with several runways and associated buildings and hangers. Many of these buildings are left from DOD ownership; however, all are being or have been put to beneficial uses since the property was declared excess. The Prisoner of War camp has been expanded and modified as the Ware County Prison. Other DOD property which comprised the former Waycross Army Airfield is being used as an industrial park and contains a lumber yard, Scott Housing Systems, Inc., Sue Bee Honey, and other businesses. Former DOD buildings and facilities in this industrial park have been demolished or modified and the area bears little resemblance to the former airfield and training facility. Some areas on the current airport property are planted with soybeans, watermelons, and other crops. Other areas are in timber production.

Attachment 1 - Site Survey Summary Sheet

SITE SURVEY SUMMARY SHEET
FOR
PROJECT NO. I04GA059200

SITE NAME: Waycross Army Airfield.

LOCATION: Waycross, Ware County, Georgia.

DESCRIPTION OF PROBLEM: Underground fuel storage tank possibly containing petroleum products or residues associated with an airplane fueling station.

SITE HISTORY: The property was acquired partially in fee and partially in lease during the period 1943-1946 by the War Department for use as a Prisoner of War camp and for combat training. The site was declared excess in 1945 and transferred by quitclaim deed to Ware County and the City of Waycross in 1947.

AVAILABLE STUDIES AND REPORTS: Savannah District has the acquisition and disposal records.

CATEGORY OF HAZARD: Potential low-level hazardous/toxic contamination.

BASIS FOR DETERMINATION OF DOD RESPONSIBILITY: Potentially hazardous structures were installed and used by DOD and have not been used by subsequent owners.

POC/DISTRICT: Stanley Rikard, Commercial (912) 944-5816/Savannah District.

STATUS: The site is currently owned and operated by the City of Waycross and Ware County.

DESCRIPTION OF PROPOSED REMEDIAL ACTION: A two phase plan of work is proposed. Phase 1 calls for an investigation to locate the fuel tank, estimate the size and condition, and obtain bottom and vapor samples. The results from this phase will determine what actions, if any, are needed in Phase 2. Assuming "worst case" and condition (i.e., a fuel tank half full), the tank contents would be pumped into drums for proper disposal and the tank itself decontaminated. The tank would then be exposed, punctured, and backfilled to the surrounding grade.

ESTIMATED COST: $12,700.

Attachment 2 - Cost Estimate

1. COMPONENT ARMY	FY 19 87 MILITARY CONSTRUCTION PROJECT DATA	2. DATE 4 Sep 87

3. INSTALLATION AND LOCATION	4. PROJECT TITLE
Waycross Army Airfield Waycross, Ware County, Georgia	Defense Environmental Restoration Program

5. PROGRAM ELEMENT	6. CATEGORY CODE	7. PROJECT NUMBER	8. PROJECT COST ($000)
		I04GA059200	12.7

9. COST ESTIMATES

ITEM	U/M	QUANTITY	UNIT COST	COST ($000)
Construction Cost (Phase 2)				9.0
Pump tank, loads contents into drum, & decontaminate tank	LS			(5.0)
Disposal of tank contents	EA	10	0.2	(2.0)
Expose and puncture tank, backfill tank, & cover to grade	LS			(2.0)
Contingencies (10%)				0.9
Supervision & Administration (7.5%)				0.7
TOTAL CONSTRUCTION CWE				10.6
Phase 1 Investigation	LS			1.5
Design (6%)				0.6
TOTAL IMPLEMENTATION COST				12.7

10. DESCRIPTION OF PROPOSED CONSTRUCTION

A two phase plan of work is proposed. Phase 1 calls for an additional on-site investigation to locate the fuel tank, estimate the size and condition, and obtain bottom and vapor samples. The results from this phase will determine what actions, if any, are needed in Phase 2. Assuming "worst case" condition (i.e., a fuel tank half full), the tank contents would be pumped into drums for proper disposal and the tank itself decontaminated. The tank would then be exposed, punctured, and backfilled to the surrounding grade.

Attachment 3 - Site Photographs

ONE OF TWO FUELING ISLANDS AT CORNER OF FOREST ROAD AND KEEN ROAD. MAGNETOMETER INDICATED NO UNDERGROUND TANKS HERE.

ONE OF TWO FUELING ISLANDS AT CORNER OF FOREST ROAD AND KEEN ROAD. MAGNETOMETER INDICATED NO UNDERGROUND TANKS HERE.

INVENTORY PROJECT REPORT
ATTACHMENT NO. 3
PROJECT NUMBER I04GA059200
WAYCROSS ARMY AIR FIELD - WAYCROSS, GEORGIA

ONE OF TWO FUELING ISLANDS WHERE
MAGNETOMETER READINGS INDICATE A SMALL
UNDERGROUND TANK.

PART II - FINDINGS AND DETERMINATION OF ELIGIBILITY

DEFENSE ENVIRONMENTAL RESTORATION PROGRAM
FOR FORMERLY USED SITES
FINDINGS AND DETERMINATION OF ELIGIBILITY
WAYCROSS ARMY AIRFIELD
WAYCROSS, WARE COUNTY, GEORGIA
PROJECT NO. I04GA059200

FINDINGS OF FACT

1. A low-level hazardous and toxic waste removal project is proposed at the former Waycross Army Airfield, located in Ware County approximately 2 miles northwest of Waycross, Georgia. The project consists of locating an underground storage tank suspected to be located at an airport fueling station. The tank will be pumped out, filled with inert material, and sealed. The tank is a potential source of environmental contamination.

2. The Waycross Army Airfield installation consisted of 36.25 acres fee acquired by purchase, 2,533.35 acres acquired by lease, and avigation easements over 64.34 acres acquired from 1943-1946.

3. Waycross Army Airfield was used by the Army as a main base for combat crew training. Extensive improvements were made during the period the base was operational. It is difficult to determine what improvements, if any, were in existence prior to Government ownership and control. The area remained under Department of Defense (DOD) control during the period of DOD ownership and use.

4. Waycross Army Airfield was declared surplus to Army needs and on 9 November 1946, was transferred to the War Assets Administration (WAA) for disposal. By quitclaim deed dated 1 July 1947, WAA conveyed avigation easements over 64.34 acres, 36.25 acres fee, and 2,521.90 acres of leased lands with improvements to Ware County and the City of Waycross. The deed restricted use to airport purposes and contained a recapture clause. The deed stated that grantee would maintain the land and improvements for the use and benefit of the public. There was no restoration provision. Leases on 11.45 acres were allowed to expire 6 months after the end of WWII.

5. The underground tank has not been used since DOD disposal of the site. The current owner has requested its removal. There is no other evidence of unsafe debris, hazardous or toxic waste, or unexploded ordnance resulting from DOD use of the site.

PROJECT NO. I04GA059200

DETERMINATION

Based on the foregoing findings of fact, the site has been determined to have been formerly used by DOD. Moreover, it is determined that an environmental restoration project, to the extent set out herein, is an appropriate undertaking within the purview of the Defense Environmental Restoration Program, established under 10 U.S.C. 2701 et seq., for the reasons stated above.

26 Jun 87
DATE

LLOYD A. DUSCHA, P.E.
Deputy Director
Directorate of Military Programs

PART III - POLICY CONSIDERATIONS

POLICY CONSIDERATIONS
WAYCROSS ARMY AIRFIELD
WAYCROSS, WARE COUNTY, GEORGIA
PROJECT NO. I04GA059200

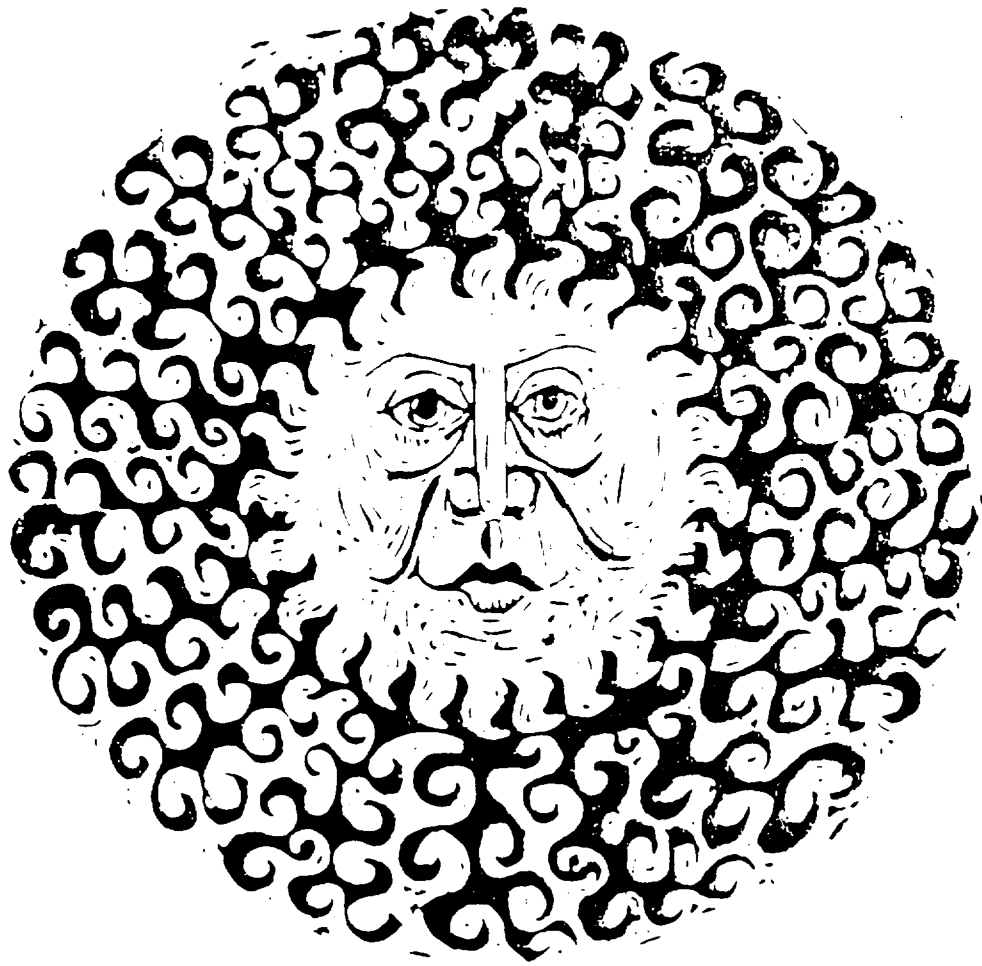
Current DOD policy permits remediation of DOD generated hazardous and toxic waste regardless of the current status of the site. With respect to the former Waycross Army Airfield, the tank was generated by DOD and has not been benficially used by the current owner.

PART IV - PROJECT RECOMMENDATIONS

PROJECT RECOMMENDATIONS
WAYCROSS ARMY AIRFIELD
WAYCROSS, WARE COUNTY, GEORGIA
PROJECT NO. I04GA059200

1. It is recommended that the project be approved as proposed. A low implementation priority is recommended, based on the low potential for direct exposure of people in the area.

[redacted]



CLIMATIC ATLAS OF THE UNITED STATES

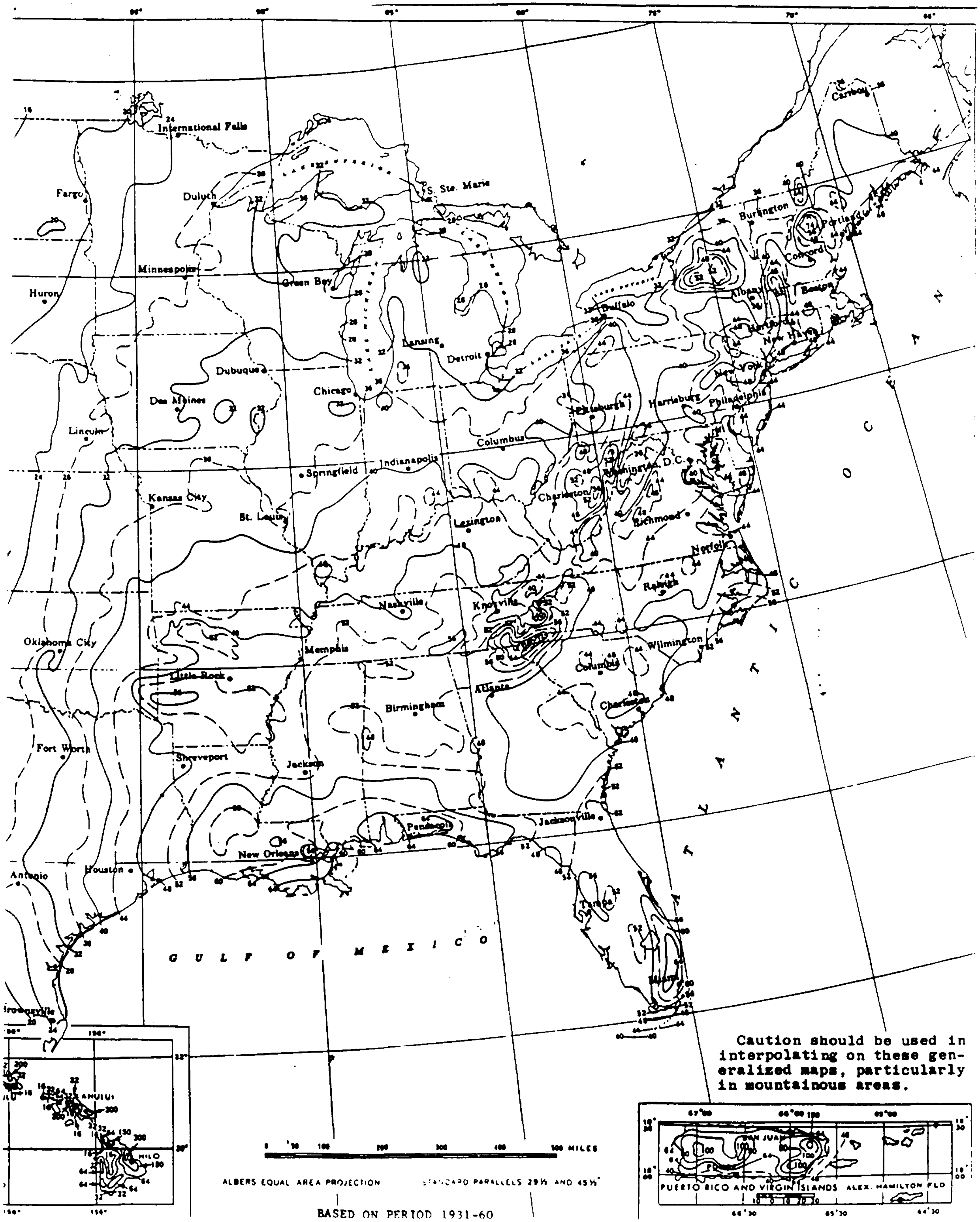
U.S. DEPARTMENT OF COMMERCE
C. R. Smith, Secretary

ENVIRONMENTAL SCIENCE SERVICES ADMINISTRATION
Robert M. White, Administrator

ENVIRONMENTAL DATA SERVICE
Woodrow C. Jacobs, Director

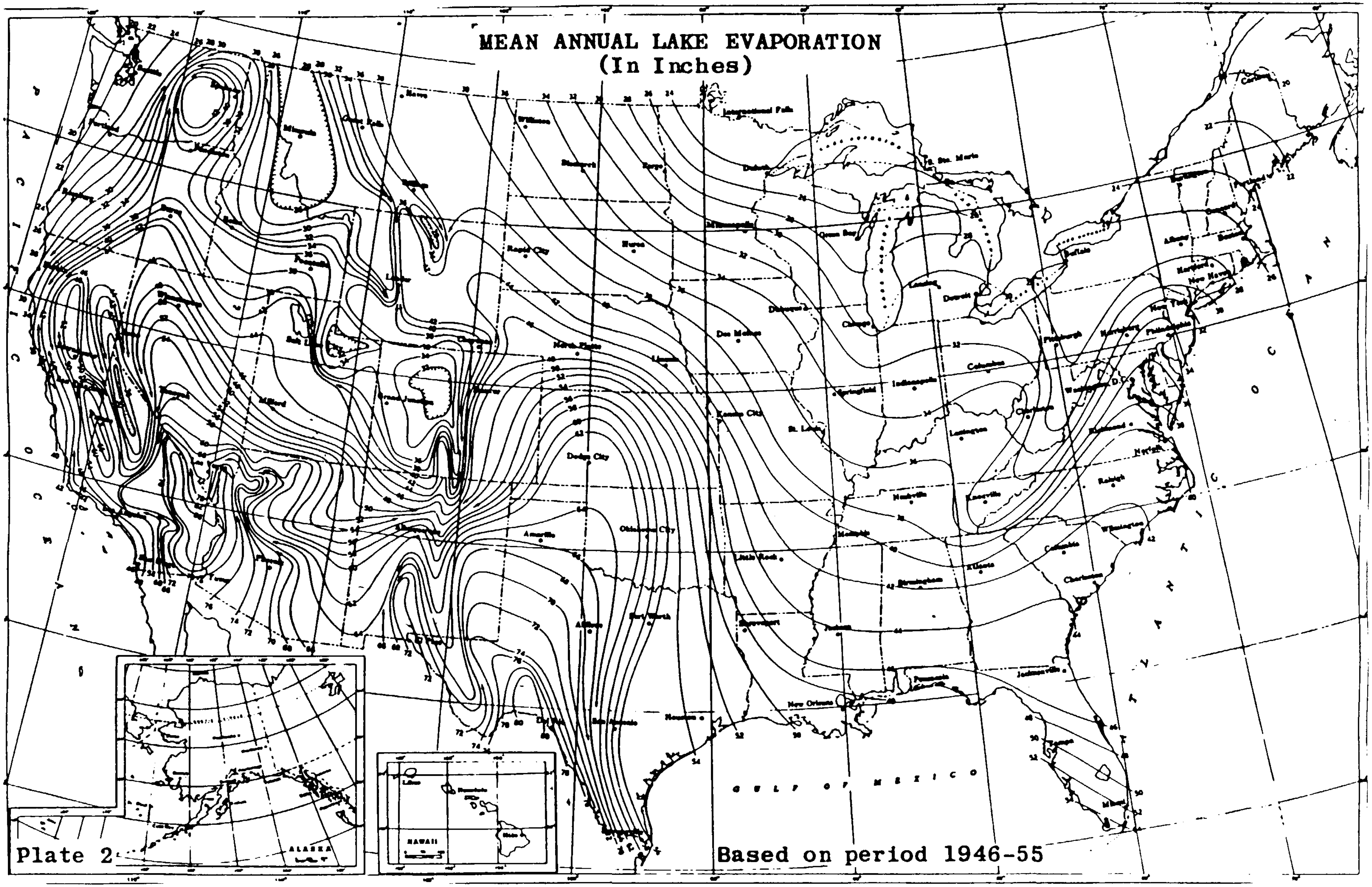
JUNE 1968

REPRINTED BY THE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
1983



Caution should be used in interpolating on these generalized maps, particularly in mountainous areas.

BASED ON PERIOD 1931-60


MEAN ANNUAL LAKE EVAPORATION
(In Inches)
Plate 2
Based on period 1946-55

U.S. DEPARTMENT OF COMMERCE
Luther H. Hodges, Secretary

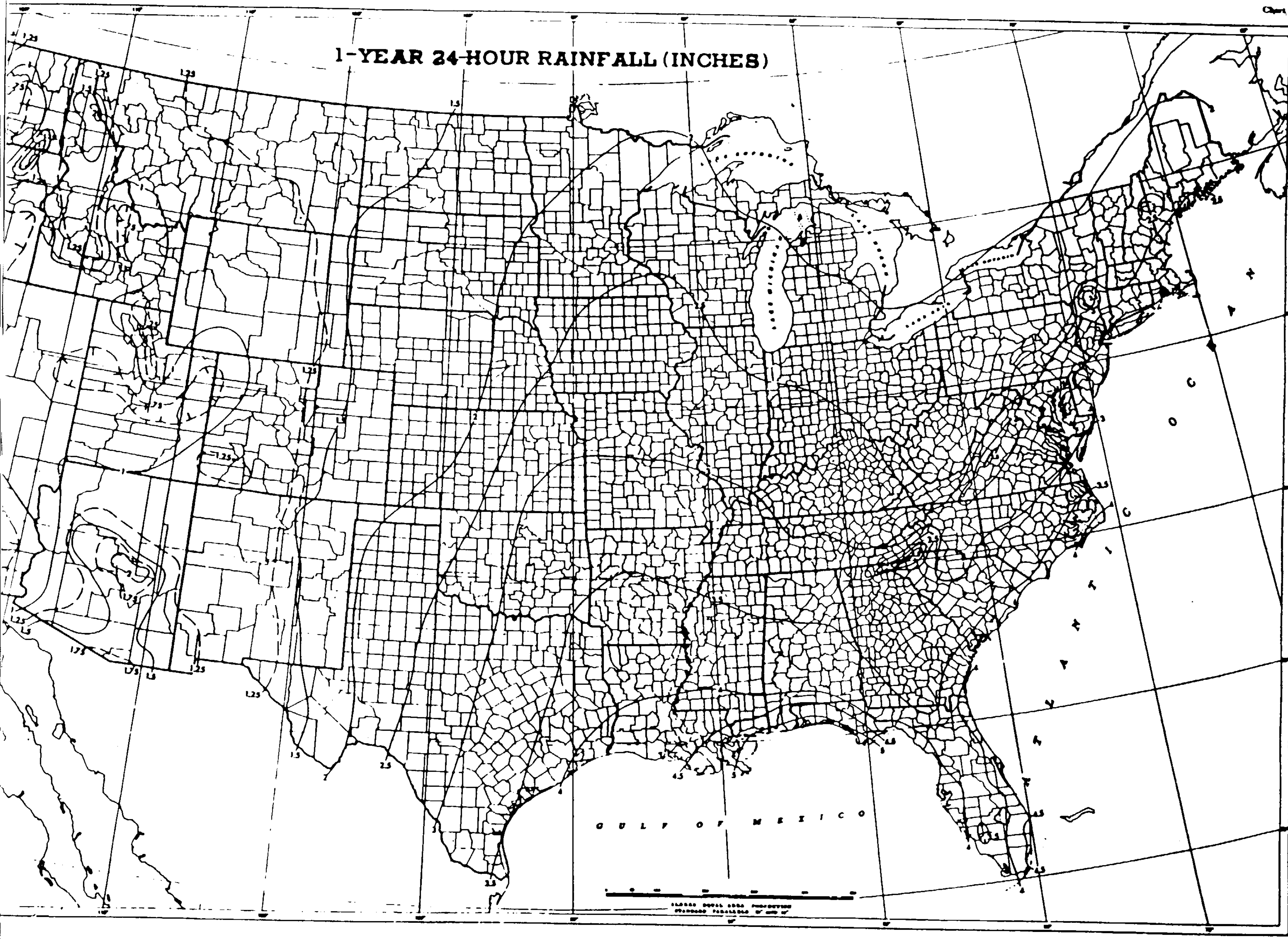
WEATHER BUREAU
F.W. Reichelderfer, Chief

TECHNICAL PAPER NO. 40

RAINFALL FREQUENCY ATLAS OF THE UNITED STATES

for Durations from 30 Minutes to 24 Hours and Return Periods from 1 to 100 Years

Prepared by
DAVID M. HERSHFIELD
Cooperative Studies Section, Hydrologic Services Division
for
Engineering Division, Soil Conservation Service
U.S. Department of Agriculture


1-YEAR 24-HOUR RAINFALL (INCHES)
GULF OF MEXICO
ATLANTIC OCEAN

DRAFT

WATER AVAILABILITY AND USE REPORT

COASTAL PLAIN RIVER BASINS

FEBRUARY 1987

GEORGIA ENVIRONMENTAL PROTECTION DIVISION

TABLE OF CONTENTS

Some of the other larger tributaries across the basin and their drainage areas are shown below.

Black Creek	296 sq. mi.
Rocky Comfort Creek	288 sq. mi.
Buckhead Creek	274 sq. mi.
Williamson Swamp Creek	275 sq. mi.
Canoochee Creek	257 sq. mi.
Lotts Creek	251 sq. mi.

The distribution of these and other tributaries is such that the only area with severly restricted surface water availability is the northwest corner of the basin at the headwaters of the Ogeechee River.

The largest city in the basin is Statesboro with a population of about 15,000. However, the largest population center consists of the outskirts of the Savannah Standard Metropolitan Area in Chatham, Bryan, and Effingham counties.

Most of the basin's landmass is undeveloped forest land. Of the small portion that is developed, most is used for agricultural purposes, including cropland and pastures. Fort Stewart Military Reservation occupies almost ten percent of the basin's land area.

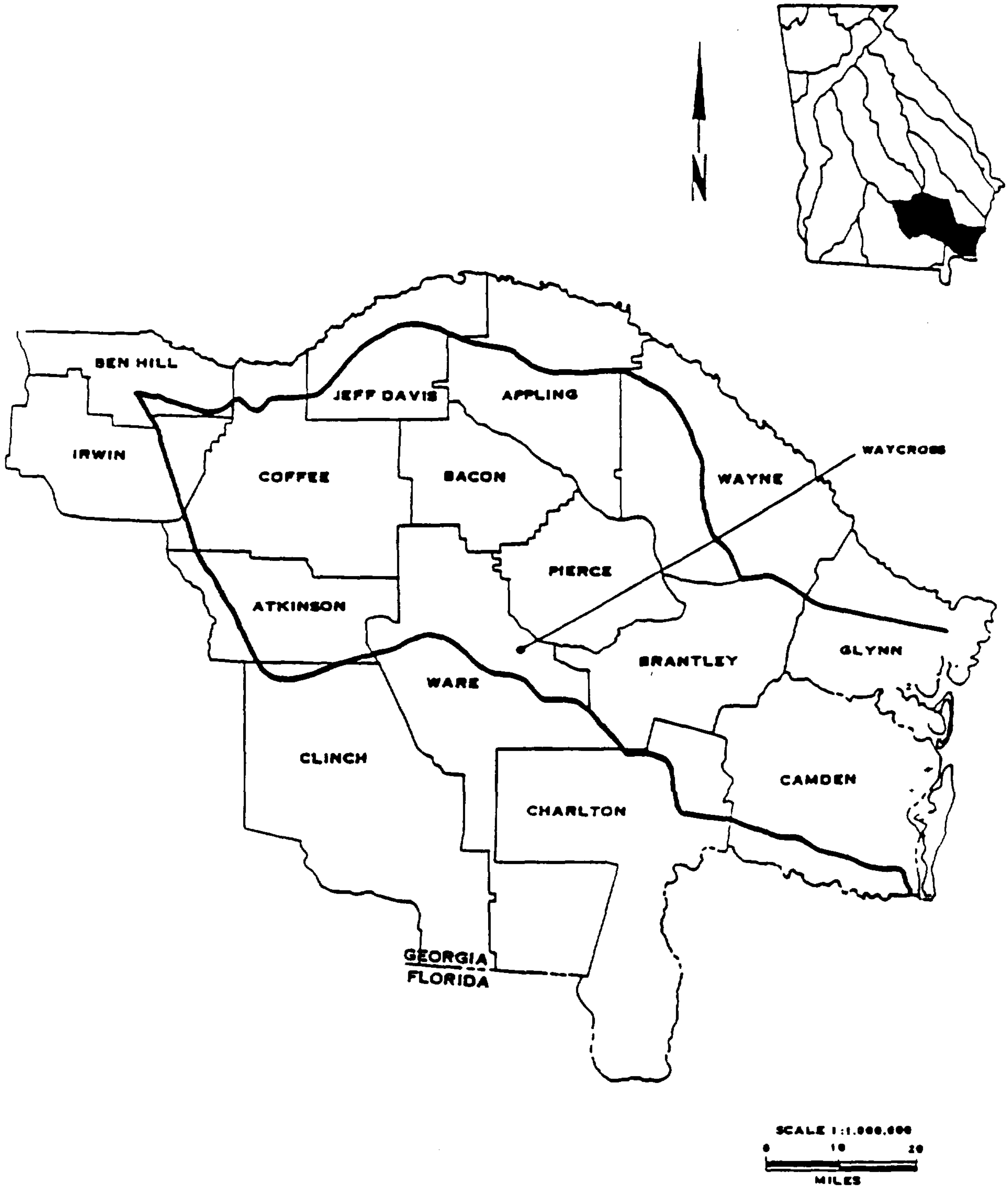
The Satilla River Basin

The first of the river basins in the study area located entirely within the Coastal Plain physiographic province is the Satilla basin (see Figure 5). With a landmass of approximately 3940 square miles, the basin includes all of Bacon, Brantley, and Pierce counties and portions of twelve others. The basin's major surface water body, the Satilla River, meanders easterly for almost 250 miles prior to discharging into the Atlantic Ocean about ten miles south of Brunswick, between Jekyll Island and Cumberland Island.

With an average annual discharge at its mouth of approximately 2700 cfs, the Satilla River is the basin's major surface water body; however, there are several tributaries with significant flows of their own. Some of the major streams and their tributary areas are shown below.

Little Satilla River	815 sq. mi.
Alabaha River	456 sq. mi.
Big Satilla River	414 sq. mi.
Seventeen Mile Creek	305 sq. mi.
Hurricane Creek	228 sq. mi.

The areas of least surface water availability are the headwaters of most of the tributaries along the northern boundary of the Satilla River Basin. As the tributaries approach their lower extremities and merge with other streams, the available flow becomes much more reliable. However, the topographical characteristics of the Satilla and other Coastal Plain basin are such that they do not produce surface runoff to the extent that the basins of the



COASTAL PLAIN RIVER BASINS WATER AVAILABILITY AND USE REPORT	GEORGIA ENVIRONMENTAL PROTECTION DIVISION	SATILLA RIVER BASIN WITH COUNTIES FIGURE 5

Piedmont, Valley and Ridge, and Blue Ridge Mountains provinces do. Relatively small stream flow rates during low-flow periods typify rivers in the Coastal Plain. Indeed, many of the smaller streams have virtually no flow during extended dry periods.

Less than three percent of the 3940 square-mile basin is devoted to urban use. More than 75 percent of the basin is covered with woodlands and marshes. Much of the remainder is agricultural cropland and pastures. The largest population centers are Waycross, Brunswick and Douglas.

The St. Marys River Basin

With a landmass of only 765 square miles in southeast Georgia, the St. Marys River Basin is the smallest of the study area's five basins (see Figure 6). An additional 535 square-mile portion of the St. Marys basin lies in Florida. The basin is one of three basins in the study area whose hydrologic boundaries continue into Florida.

The upstream boundary of the St. Marys River Basin is the Okefenokee Swamp. From this point the Georgia portion of the basin extends eastwards and northward to include parts of Ware, Charlton, and Camden counties.

Surface water resources in the basin are limited by its small size. The main stem of the St. Marys River is the principal surface water resource, with an annual average flow at its mouth of about 1400 cfs. The North Prong St. Marys River and Spanish Creek, with tributary areas of 540 square miles and 109 square miles, respectively, are the only significant tributaries. As with the previous two basins, the St. Mary's has no major impoundments.

The basin's largest population centers are St. Marys and Folkston, each with populations of less than 5000. These population figures are expected to change rapidly with the continuing development of the Kings Bay submarine facility and secondary growth in Camden County. The vast majority of the St. Mary's basin is undeveloped and covered by woodlands, swamps, and marshes.

The Suwannee River Basin

The Suwannee River Basin is the second basin in the study area which extends into Florida. With its headwaters in the northwest quadrant of Dooly County, the basin extends southward through the Georgia-Florida border into Florida, and eastward to the Okefenokee Swamp (see Figure 7). Approximately 5560 square miles of the basin's 11,020 square miles are within Georgia. The Suwannee River Basin is one of two study area basins, the other being the Ochlockonee, that ultimately discharges to the Gulf of Mexico.

The principal surface water resources are the three major rivers which drain portions of the basin. The eastern portion of the basin contains the headwaters of the Suwannee River (average annual flow 1580 cfs). The central portion is drained by the Alapaha River (average annual flow 1045 cfs), which joins the Suwannee River about 15 miles south of the state line. The western portion of the basin comprises the Withlacoochee River watershed, (average annual flow 1580 cfs) which joins the Suwannee River about eight miles downstream from the confluence of the Suwannee and Alapaha rivers. The three major rivers thus cross the state line separately, but they join long before the Suwannee reaches the Gulf of Mexico.

Tributaries of major significance are listed below.

Little River	875 sq. mi.
Okapilco Creek	726 sq. mi.
Suwanoochee Creek	455 sq. mi.
Willacoochee River	251 sq. mi.
Little River	242 sq. mi.

Valdosta and Tifton are the largest population centers in the basin, with Moultrie and Fitzgerald also of significant size.

As with the previously described basins, the Suwannee's landmass is by and large undeveloped and covered by woodlands. The much-renowned Okefenokee National Wildlife Refuge is a large wilderness area along the eastern extremity of the basin. Agricultural cropland and pastures again comprise the majority of the developed land in the basin.

The Ochlocknee River Basin

The Ochlockonee River Basin (See Figure 8) is the study area's second basin with an eventual discharge to the Gulf of Mexico, and the third to share landmass with Florida. The basin's headwaters are in Worth County. Of its 6330 square miles, approximately 1460 square miles are within Georgia.

The main stem of the Ochlockonee River and its tributaries are the principal surface water resources in the basin. The annual average flow of the river as it crosses the Georgia-Florida border is estimated at 850 cfs, with a 7Q10 estimate of 24 cfs.

One of the unique features of the Ochlockonee River Basin is the presence of two smaller watersheds, the Aucilla River and Ward Creek watersheds, each of which discharge their waters separately into the Gulf of Mexico without ever merging with the waters of the Ochlockonee River. Thomasville is the basin's largest population center in Georgia. Land use in the basin is similar to the previously mentioned land use patterns in the study area.

Ground Water

Geologic Setting of the Study Area

The state of Georgia can be divided into four major geologic Provinces: the Ridge and Valley Province (northwest Georgia), the Blue Ridge Province (northeast Georgia), and Piedmont Province (north-central Georgia), and the Coastal Plain Province (southern half of the state) (Lawton, 1977). As can be seen by the map in Figure 2, the study area lies almost exclusively in the Coastal Plain Province.

The geology of the Coastal Plain Province consists of a thin (central Georgia) to very thick (southeastern and southwestern Georgia) sequence of stratified sediments deposited upon a predominately igneous and metamorphic rock complex. These "basement" rocks also contain areas of Triassic, Paleozoic, and possibly Jurassic sedimentary rocks. At the geologic Fall Line in Georgia (i.e., a line which approximately connects the cities of Columbus, Macon, and Augusta, and is the dividing line between the Georgia Piedmont and the Coastal Plain Province), these sediments consist of only a few feet of sand and gravel. Downdip, to the south of the Fall Line, the sediment lithology changes to sand, clay, and limestone. The sediment thickness increases to over 7000 feet in southwestern Georgia (Arora and others, 1984). The dip of bedding stratification in the Coastal Plain is fairly gentle, ranging from as little as eight feet per mile in sediments of Miocene age to 30-40 feet per mile in deeper sediments of Cretaceous age (Thomson and others, 1956)

Structural deformation of Coastal Plain sediments is known to exist in Georgia, but is limited in both extent and intensity. Some faults are present, and gentle anticlinal and synclinal folding of sedimentary layers is fairly common. Much of the folding, however, may be due more to subsidence and differential compaction of underlying materials than to tectonic forces. Weathering and solution removal of sediments vary throughout the Coastal Plain, but can extend from the surface to substantial depths, depending upon the sediment or rock lithology present.

The geomorphology of the study area is strongly related to the underlying geology; in fact, the Coastal Plain geologic province has the same boundaries as the Coastal Plain Physiographic Province.

Geologic-Hydrologic Relationship

In the Coastal Plain Province of Georgia, the relationship between geology and the occurrence of ground water in large quantities is dependent upon sediment or rock lithology, permeability, and regional structure, or dip of the beds. South of the Fall Line, poorly consolidated sand and gravel of Cretaceous, Paleocene, and Middle Eocene age absorb and yield large volumes of water, while interbedded clay layers may contain large quantities of water yet yield relatively little. Downdip of the sand aquifers, younger carbonate aquifers contain large volumes of water under artesian pressure. Although the potentiometric head of the aquifer has diminished in recent years due to heavy localized pumping, the storage capacity of the carbonate aquifers is very large. This large storage results primarily from solution channel development throughout the limestone bed.

Hydrogeology of the Study Area

The study area encompasses a variety of ground water aquifers and aquifer systems, some major, some minor. Major aquifers underlying the study area include the Lower Cretaceous Aquifer System, the Cretaceous Aquifer System, the Dublin-Midville Aquifer Systems, the Gordon Aquifer System, the Jacksonian Aquifer, the Miocene Aquifer, the Pliocene-to-Recent Aquifer, the Floridan Aquifer, and the Providence Aquifer (Arora, et. al, 1984; Clark, et. al, 1985; Brooks, et. al, 1985; Vincent, 1982). Of lesser significance are the Clayton and Claiborne aquifers, primarily because they underlie such a minute portion of the study area.

The Jacksonian Aquifer

The Jacksonian Aquifer overlies the Gordon system in the Evans County vicinity of the Ogeechee basin. It consists of exposed updip clastic and subsurface downdip carbonate constituents. The clastic facies represent a marginal to nearshore marine depositional environment, and is characterized by sand and gravel. Downdip the aquifer sediments are gradually replaced by increasing clay, fine sand, and calcareous material (e.g. limestone) representing an offshore marine depositional environment. The aquifer's water quality is well within drinking water standards.

The Providence Aquifer

The Providence Aquifer occurs both as the Providence Aquifer and as the Providence-Cussetta Aquifer system where the Providence - Ripley confining zone is absent. Its thickness ranges from about 100 to 300 feet. Transmissivities are as high as 25,000 gpdpf, with well yields from 25 to over 300 gpm. Generally there are no water quality problems in the aquifer (Clarke, et al, 1983).

The Clayton Aquifer

The Clayton Aquifer overlies the Providence-Cussetta System, and lies along the western edge of the Suwannee and Ochlockonee basins. The Clayton consists mostly of saturated, permeable limestones. Transmissivities in the Clayton in Dooly and Crisp counties range from about 1500 to 45,000 gpdpf. The yield of the aquifer in the area is too low for reliable municipal, industrial, or irrigation use.

The Claiborne Aquifer

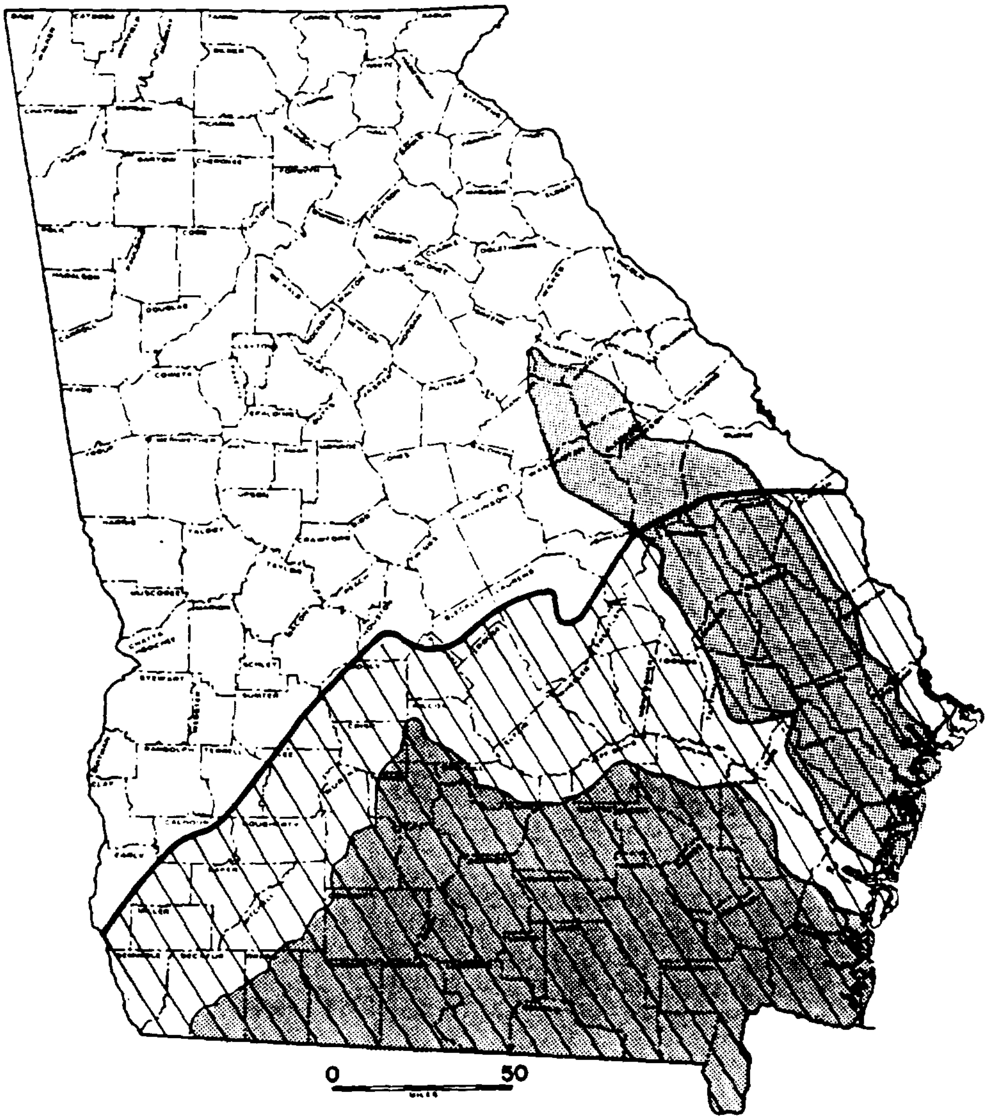
Overlying the Clayton Aquifer is the Claiborne Aquifer (see Figure 10), which generally consists of saturated, permeable sands of the Tallahatta Formation. Further downdip, the western Colquitt and eastern Mitchell counties, the Tallahatta becomes predominantly limestone (Zimmerman, 1977). Claiborne Aquifer transmissivities have been calculated in excess of 75,000 gpdpf in Dooly and Crisp counties. The aquifer is widely used in the two counties for municipal and irrigation water supplies. Again, water quality concerns are minimal to non-existent (McFadden and Perriello, 1985).

Further downdip in the Ogeechee River Basin, the predominately clastic sediments of the Jacksonian Aquifer grade into the carbonate rocks of the Floridan Aquifer. In the Suwannee, Ochlockonee, Satilla, and St. Marys basins, the Tallahatta and underlying aquifers increase in depth toward the Georgia coast and Florida border. Overlying these aquifers the Floridan Aquifer thickens and increases in areal extent until it becomes the predominant aquifer in the southern part of the study area (Figure 11).

The Floridan Aquifer

Overlying the Cretaceous Aquifer System throughout most of the Georgia Coastal Plain is the Floridan Aquifer System (formerly known as the Principal Artesian Aquifer). The Floridan Aquifer System contains water under artesian

FLORIDAN AQUIFER



COASTAL PLAIN RIVER BASINS WATER AVAILABILITY AND USE REPORT	GEORGIA ENVIRONMENTAL PROTECTION DIVISION	FLORIDAN AQUIFER FIGURE 11

pressure. Due to the large volumes of good quality water contained in most of this aquifer, it is the most heavily developed and productive aquifer in the State of Georgia.

Within the study area, the Floridan Aquifer consists of the Middle Eocene Bug Island and Gulf Hammock Formations, the Upper Eocene Ocala Group, and the Oligocene Suwannee Limestone. The aquifer is generally divided into two main water-bearing zones. The upper zone includes the Suwannee Limestone and the upper portion of the Ocala Group, while the lower zone consists of the basal portion of the Ocala Group and the Bug Island Formation. A confining zone approximately 100-150 feet thick separates these two zones (Krause & Greeg, 1972). The aquifer lithology is predominantly limestone in the study area, confined above and below by clay and calcareous sediments of low permeability.

The main area of outcrop of the Floridan aquifer lies in a broad band across the Coastal Plain of southwest Georgia. This outcrop area also serves as the main zone of aquifer recharge. Recharge to the aquifer system occurs from streams and rivers that flow across the outcrop, from percolation of water down through sinkholes, and from infiltration of water downward through overlying permeable sediments. The units which make up the Floridan Aquifer System in the study area are predominantly of carbonate lithology, although beds of sand, clay, and silt are locally present. Solution leaching of the carbonates in the aquifer has enlarged subsurface flow paths considerably, so that large volumes of water migrate downdip through interconnecting channels and zones of high permeability. In some portions of the main recharge area in Georgia, large volumes of water are discharged from the aquifer through springs. Such spring flow in the recharge area of Georgia is essentially a discharge of ground water that cannot flow downdip through the aquifer system under existing hydraulic gradients. Prior to existing development there were large areas in coastal Georgia where water was discharged from the Floridan Aquifer to the overlying surficial aquifer. Due to increased pumpage, these areas have since become areas of reduced recharge (Randolph and Krause, 1984).

The Floridan Aquifer System in Georgia is essentially wedge-shaped, with the thin edge laying close to the Fall Line, and thick sections laying to the southeast and south of the study area, along the coast and along the Georgia-Florida border. Clastic sediments equivalent in age to the limestones of the Floridan Aquifer occur in southern Washington County. Downdip towards the Atlantic Coast, the clastic sediments grade into limestones and the aquifer thickens to as much as 2700 feet in Glynn County. The overlying strata in the study area ranges in thickness from zero to more than 60 feet (Arora, et al, 1984).

Development and usage of ground water resources from the Floridan Aquifer over the study area is of two basic types. First, there are localized large quantities of water pumped from the aquifer along the coast, primarily for use by chemical and paper industries. Such is the case in Brunswick and portions of the St. Marys- Fernandina Beach areas. Although not within the study area, heavy localized pumping in the metro Savannah area has adversely affected well levels in the lower Ogeechee River Basin. In the Brunswick area potentiometric surfaces have declined as much as 70 feet since 1880 (Warren, 1944; Krause and Hayes, 1981), resulting in partial reversal of aquifer discharge patterns beneath the ocean. In one small area between St. Marys and Fernandina Beach, where the potentiometric surface stood at about 60 feet above sea level in 1880, it now stands as low as 20 feet below sea level.

The second major type of ground water use from the aquifer is the pumpage of moderate to large quantities of water for irrigation and public water supplies. The character of agricultural irrigation is such that use is necessarily of a very dispersed nature, therefore large cones of depression are atypical. Areas in the southwestern portion of the study area, principally in the Ochlockonee and Suwannee basins, and to a lesser extent the Satilla River Basin, are typical of this type of use. Sparse population densities demanding smaller quantities of water for public supply also contribute to the dispersed character of ground water usage in these areas.

Associated with heavy localized pumping from the Floridan Aquifer are localized changes in the quality of the aquifer's water. In the Brunswick area, lowering of the potentiometric surface in the aquifer's upper fresh water-bearing zone has caused up-migration of brackish waters from the lower water-bearing zone. This phenomenon is exacerbated by the presence of an ineffective confining bed between the freshwater and salt water-bearing zones (Wait and Gregg, 1973). Similar contamination of the freshwater-bearing zone by saline water occurs in the aquifer in the St. Marys River Basin as it approaches Nassau County, Florida (Leve, 1966). In some instances in the aquifer, up-migration of brackish water is attributable to improperly contructed wells being drilled beyond the upper water-bearing zone and into the brackish lower water-bearing zone, therefore allowing contamination of the better quality waters above.

Well yields from the Floridan Aquifer in and around the study area range from 500 to 10,000 gallons per minute. The transmissivity is estimated to range from as low as 2,000 gpdpf to as high as 1,600,000 gpdpf. In the Brunswick area, when testing both water-bearing zones, the transmissivity was estimated at 1,400,000 gpdpf and the storage coefficient at 0.004 (long-term pumping) (Wait and Gregg, 1973).

Well yields from the Floridan Aquifer in the study area can be quite high. Yields range from as little as 20 gallons per minute (gpm) for small domestic wells to more than 10,000 gpm for some of the larger industrial wells.

The Miocene Aquifer

In the study area the Miocene Aquifer lies directly upon the Floridan Aquifer. The Miocene Aquifer consists primarily of the Hawthorne Group of Miocene age, which is predominantly sand and clay, but also includes interbedded limestones. The Hawthorne Group crops out at the surface over a large portion of the Suwannee River Basin and towards the upper Coastal Plain in the Ogeechee basin.

The Hawthorne Group varies in thickness from less than 100 feet in Wilcox Emanuel, Thomas, and Brooks counties to 600 feet in some areas of Tift, Colquitt, and Evans counties. The thickening of the Miocene Aquifer in these areas has been attributed to the formation of the Gulf Trough, which resulted in down warping and thickening of the sediment layers. The aquifer consists primarily of sands and clays which grade from clean to all degrees of intermixing.

The aquifer provides water supplies from some of the more permeable beds, but production is relatively minor. Where adequate water supplies can be obtained from the aquifer (usually domestic supply), the quality of the water from the Hawthorne Group is generally good to excellent. Dissolved solids rarely exceed 400 mg/l, and are frequently less than 200 mg/l.

The Pliocene-to-Recent Aquifer

The uppermost aquifer present in the study area is the Pliocene-to-Recent Aquifer. Practically the entire aquifer's exposed surface is outcrop and recharge areas. The aquifer extends to depths of about 70 feet and is easily contaminated by spills and leakage of deleterious materials.

Most wells which tap the Pliocene-to-Recent Aquifer for potable water are shallow domestic wells, as the aquifer is not a reliable source over extended dry periods.

ASSESSMENT METHODOLOGY

Collection, organization, and evaluation of data from several sources are necessary in the preparation of this report. The study area is first divided into five distinct river basins, then the basins are further sub-divided into hydrologic units as appropriate for each basin. Major water users within the study area who are required to obtain state water use permits are identified and organized based upon the respective river basin and hydrologic unit in which the use occurs. For permitted surface water withdrawers, past and future water usage is compared to the historic resource availability so as to identify existing and potential water availability problem areas.

While ground water use is fairly tractable quantitatively in the study area, its availability is not nearly as definitive. The report therefore describes available ground water resources in a more qualitative manner, making use of known quantities when such figures are available. Further, because the availability and distribution of ground water is based on the lithology and stratigraphy of the study areas more so than its topography, the description of available ground water supplies is done on the basis of study area's geology rather than by river basin.

In estimating the total water use in each basin, the study considers water use by both permitted facilities and facilities not currently required to have permits.

Data Sources

The data presented in this report were obtained from several sources, and supplemental data were developed as needed.

Surface water availability data were taken primarily from streamflow gaging records published by the U.S. Geological Survey (USGS). Data from 12 continuous recording gaging stations were evaluated during the study.

Georgia water use data are maintained on file by EPD. The Water Resources Management Branch collected the data on the permitted water withdrawal

GEORGIA

[illegible]

[illegible]

[illegible]

[illegible]

[illegible] OF THE

COASTAL PLAIN OF GEORGIA

[illegible]

[illegible]

[illegible]

ATLANTA

[illegible]

	Thickness (feet)	Depth (feet)
Limestone: white, sandy; sand, coarse-grained, subrounded grains	?	90
Sand: fine to medium-grained, angular, fossiliferous (some macroshells); some clay, yellowish-green	?	150
Clay: yellowish-green, sandy, finely disseminated phosphatic grains, fossiliferous (echinoid and bryozoan remains, Ostracods, and Foraminifera)	?	245

Siphonina jacksonensis, Valvulineria jacksonensis, Nonion advena, Cibicides cf. *C. refulgens, Cibicides lobatulus* at 245.

Summary:

	Thickness (feet)	Depth (feet)
No samples	55	55
In upper Eocene (Barnwell formation)	190	245

Potential Water-Bearing Zones:

None observed in samples available for this well.

WAYNE COUNTY

Location: 8.5 mi. southeast of Jesup, Land Lot 7, 333rd Land District
Owner: Brunswick Peninsular Corporation
Driller: The California Co.
Drilled: December 1944

Well No.: GGS 52
Elev.: 73 (derrick floor)

	Thickness (feet)	Depth (feet)
No samples	74	74

In Miocene (Undifferentiated):

	Thickness (feet)	Depth (feet)
Sand: fine to coarse-grained, angular, phosphatic; limestone, gray to cream, dense (calcitized), sandy, phosphatic, fossiliferous (molds and impressions of macroshells)	389	463
Sand: as above; clay, dark-green, sandy, fossiliferous (macroshells and fish teeth)	31	494
Sand: fine to coarse-grained, phosphatic; limestone, white, sandy	29	523
Sand: fine to coarse-grained, phosphatic; dolomitic limestone, light-brown, saccharoidal, phosphatic	157	680

	Thickness (feet)	Depth (feet)
ɜd, subrounded ...	?	90
ɹliferous (some ...	?	150
ɩted phosphatic ˀemains, Ostra- ...	?	245

nensis, *Nonion* *ɩbatulus* at 245.

...	55	55
...	190	245

: Zones:

WAYNE COUNTY

7, 333rd Well No.: GGS 52
Elev.: 73
(derrick floor)

	Thickness (feet)	Depth (feet)
...	74	74
atic; limestone, osphatic, fossil- lls) ...	389	463
iferous (macro- ...	31	494
mestone, white, ...	29	523
mitic limestone, ...	157	680

	Thickness (feet)	Depth (feet)
Oligocene (Undifferentiated):		
Sand and limestone: as above; limestone, light-gray, nodular, dense (calcitized), fossiliferous (some Foraminifera)	45	725
Quinqueloculina sp., *Pyrgo* sp. at 680-710. *Dictyoconus*[1] sp. at 710-725.		
Limestone: cream, fossiliferous; some dolomitic limestone, as above	14	739
Upper Eocene: Jackson Group: Ocala Limestone:		
Limestone: cream to light-gray, massive, dense (much calcitized), fossiliferous (macroshells, bryozoan remains, and some Foraminifera)	94	833
Asterocyclina nassauensis, Gypsina globula at 756-771. *Pseudophragmina flintensis, Operculinoides floridensis* at 771-787.		
Limestone: as above; some dolomitic limestone	62	895
Middle Eocene: Claiborne Group (Undifferentiated):		
Sand: fine to coarse-grained, and some dolomitic limestone, as above	88	983
No samples	99	1,082
Dolomitic limestone: brown, saccharoidal	54	1,136
Dolomitic limestone: as above; some limestone, light-gray, saccharoidal, granular (in texture)	16	1,152
No samples	31	1,183
Limestone: light-gray, somewhat granular (in texture), finely disseminated glauconite, fossiliferous	167	1,350
Asterocyclina monticellensis at 1183-1214. *Lepidocyclina (Polylepidina) antillea* at 1245-1255.		
Sand: fine to coarse-grained, phosphatic; interbedded limestone, cream, somewhat massive	280	1,630
Sand: as above; dolomitic limestone, light-brown, saccharoidal, cherty	77	1,707
Limestone: cream, granular (in texture), dense (much calcitized), cherty	243	1,950
Asterocyclina monticellensis common at 1857-1873.		

[1]Reworked(?) fossil of middle Eocene age.

	Thickness (feet)	Depth (feet)
Dolomitic limestone: light-brown, saccharoidal; some limestone, as above	40	1,990
Dolomitic limestone: as above, but coarsely glauconitic	5	1,995
Dolomitic limestone: as above; some indurated sand, fine-grained, abundantly glauconitic; interbedded clay, pale-green, fissile, silty, gypsiferous, finely glauconitic, abundantly and coarsely glauconitic and fossiliferous at depth	125	2,120
Sand: fine to coarse-grained, phosphatic	85	2.205
Lower Eocene: Wilcox Group (Undifferentiated):		
Sand: fine to coarse-grained, glauconitic; interbedded limestone, white, dense (much calcitized), sandy, coarsely glauconitic, fossiliferous (molds and fragments of macroshells)	165	2,370
Eponides dorfi, *Valvulineria wilcoxensis* at 2205-2212.		
Marl: dark-gray, silty, micaceous, carbonaceous, fossiliferous (some Foraminifera)	175	2,545
Eponides dorfi, *Valvulineria scrobiculata*, *Cibicides howelli* at 2473-2545.		
Paleocene: Midway Group: Clayton Formation:		
Sand: somewhat indurated at certain horizons, fine-grained, glauconitic; interbedded marl, dark-gray to black, fissile, carbonaceous, finely micaceous, fossiliferous (some Foraminifera)	90	2,635
Eponides lotus, *Polymorphina cushmani*, *Siphonina prima*, *Cibicides praecursorius*, *Cibicides howelli* at 2545-2550.		
Limestone: cream, dense (much calcitized), nodular (in texture), somewhat saccharoidal, fossiliferous (molds of macroshells, bryozoan remains, and occasional Ostracods and Foraminifera)	24	2,659
Sand: somewhat indurated at certain horizons, fine-grained, micaceous, glauconitic	121	2,780
Sand: fine-grained, glauconitic; interbedded marl, black, fissile, carbonaceous, finely micaceous, somewhat fossiliferous (Foraminifera)	120	2,900
Upper Cretaceous: Post-Tuscaloosa (Undifferentiated):		
Marl: bluish-gray to brown, sandy, micaceous, glauconitic, fossiliferous (macroshells, Ostracods, and Foraminifera)	625	3,525
Globotruncana sp., *Guembelina* sp. at 2900-2903.		

	Thickness (feet)	Depth (feet)
Marl: as above, but much sandier	540	4,065
Anomalina sp., *Globorotalia micheliniana* at 3525-3540.		
Planulina cf. *P. taylorensis* at 3540-3555.		
Kyphopyxa christneri at 3612-3626.		
Vaginulina texana at 3693-3708.		
Sand: fine to medium-grained, somewhat indurated at certain horizons, glauconitic, phosphatic, abundantly micaceous	65	4,130
Tuscaloosa Formation:		
Sand: fine to medium-grained, indurated, finely glauconitic, very micaceous, fossiliferous (macroshells); interbedded shale, greenish to dark-gray, fissile, finely micaceous	445	4,575
Basement Complex (Undifferentiated):		
Quartzite?	50	4,625

Summary:

No samples	74	74
In Miocene (undifferentiated)	606	680
Oligocene (undifferentiated)	59	739
Upper Eocene (Ocala limestone)	156	895
Middle Eocene (Claiborne group, undifferentiated)	1,310	2,205
Lower Eocene (Wilcox group, undifferentiated)	340	2,545
Paleocene (Clayton formation)	355	2,900
Upper Cretaceous (post-Tuscaloosa, undifferentiated)	1,230	4,130
Upper Cretaceous (Tuscaloosa formation)	445	4,575
Basement complex (undifferentiated)	50	4,625

Potential Water-Bearing Zones:

Limestone	180	860
Sand: fine to coarse-grained	61	956
Sand: fine to coarse-grained	280	1,630
Sand: fine to coarse-grained	70	2,370
Sand: fine-grained[1]	65	2,635

[1]Probably contains salt water.

OVERSIZED

DOCUMENT